KEITHLEY

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Models 3321, 3322, 3

KEITHLEY 3330

LCZ METER
SERVICE MANUAL MET41101

DUPLICATE
EXIST
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maxell
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Model 3330 LCZ
Adjustment Software.

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Models 3321, 3322, 3330, 3910, 3930A, 3933A, 3940 Operator's/Service Manual Addendum

Introduction

This manual addendum is being provided in order to supply you with the latest information in the least possible time. Please review these changes and incorporate them into the manual before operating or servicing the unit.

Line Fuse Type

This addendum concerns the line fuse type listed in the operator's and service manuals for the following instruments:

- Model 3321 LCZ Meter
- Model 3322 LCZ Meter
- Model 3330 LCZ Meter
- Model 3910 Function Synthesizer
- Model 3930A Multifunction Synthesizer
- Model 3933A Phase Shifter
- Model 3940 Multifunction Synthesizer

The line fuse type for all the above instruments should be listed as slow blow instead of normal blow (as now indicated in the manual, and possibly on the instrument's rear panel). Any line fuse part numbers that are listed in the manual should also be disregarded.

Table 1 lists the Keithley and Littelfuse part numbers for replacement fuses. Refer to the instrument rear panel for the fuse rating appropriate for the line voltage. Note that in all cases you should use a slow blow fuse of the same rating as shown on the rear panel.

CAUTION

Do not use a fuse with a higher current rating than specified on the rear panel, or instrument damage may occur.

Table 1. Fuse part numbers (slow blow, 250V maximum, 5 ×20mm)

Model number	Line voltage	Fuse rating	Keithley part no.	Littelfuse part no.
3321, 3322, 3330	100V/120V	0.4A	FU-80	239.400
		0.5A	FU-71	239.500
	220V/240V	0.2A	FU-96-3	239.200
		0.25A	FU-96-4	239.250
3910	100V/120V	0.5A	FU-71	239.500
		1A	N/A	239 001
	220V/240V	0.25A	FU-96-4	239.250
		0.5A	FU-71	239.500
3930A, 3933A	100V/120V	0.8A	FU-52	239.800
		1A	N/A	239 001
	220V/240V	0.4A	FU-80	239.400
		0.5A	FU-71	239.500
3940	100V/120V	2A	FU-81	239 002
	220V/240V	1A	N/A	239 001
		2A	FU-81	239 002

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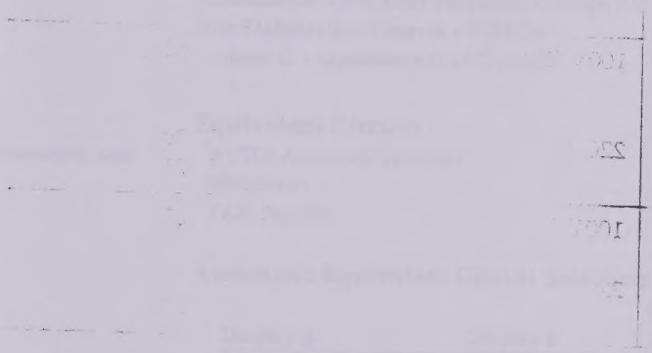
3330 LCZ Meter

Operator's Manual Addendum

Introduction

This addendum to the Model 3330 Operator's Manual is being provided in order to supply you with the latest information in the least possible time. Please incorporate these changes into the manual immediately.



APPENDIX A
Model 3330 Specifications

A.1 MEASUREMENT PARAMETERS

Main Parameters (Display A) and Range

L: Inductance, 0.1nH to 19.999kH
C: Capacitance, 0.001pF to 199.99mF
R: Resistance, 0.1mΩ to 19.999MΩ
|Z|: Magnitude of impedance, 0.1mΩ to 19.999MΩ
AUTO: Automatically selects main parameters, sub-parameters, and equivalent circuit.

Sub-parameters (Display B) and Range

Q: Quality factor, 0.0001 to 19999
D: Dissipation factor, 0.0001 to 19999
ESR: Equivalent series resistance, 0.1mΩ to 19.999MΩ
G: Parallel conductance, 0.001μS to 199.99S
X: Series reactance, 0.1mΩ to 19.999MΩ
θ: Phase angle of impedance, –180.00° to +179.99°
V: Voltage monitor (RMS voltage across device) 0.0mV to 1.999Vrms
I: Current monitor (RMS current through device), 0.00μArms to 19.99mArms

Measurement resolution will vary depending on frequency, measurement range, and impedance phase angle.

Automatic Parameter Selection

Phase	Display A	Display B
+120° to +60°	L	Q
+30° to -30°	R	Q
-120° to -60°	C	D
others	|Z|	θ

Deviation Measurement

Δ: Deviation of main parameter (range of deviation is at least ±100% of the measurement range)
Δ%: % deviation display of main parameter (display range ±199.99%)
Note: Deviation and % deviation of sub-parameters cannot be displayed.

Execution Times

Measurement Time (IEEE-488)
FAST: 65msec (typ)
MED: 155msec (typ)
SLOW: 485msec (typ)
Note: 1kΩ impedance, 1kHz frequency and one shot trigger.

Autoranging Time: Approximately equal to measurement time
Stabilization Time After Range Change: 0.2 - 4.0s
Stabilization Time After Frequency Change: 0.15 - 4.0s
Bias Stabilization Time: (4 + 0.015C)s
where: C = capacitance of DUT (in μF)

Equivalent Circuits

AUTO: Automatic selection
SER: Series
PAR: Parallel

Automatic Equivalent Circuit Selection

Display A	Display B	Equivalent Circuit
L, C, R or |Z|	ESR or X	Series
L or C (|Z| ≤1kΩ)	Q, D, θ, V or I	Series
R (θ ≥ 0)	Q, D, θ, V or I	Series
|Z|	Q, D, θ, V or I	Series
L, C, R, or |Z|	G	Parallel
L or C (|Z| > 1kΩ)	Q, D, θ, V or I	Parallel
R (θ < 0)	Q, D, θ, V or I	Parallel

Displayed Resolution

4-1/2 digits (19999 max counts)
D, Q maximum resolution: 0.0001
θ resolution: 0.01°
V resolution: 0.1mV
I resolution: 1μA (when reference resistance is 100Ω)
0.1μA (when reference resistance is 1kΩ)
0.01μA (when reference resistance is 10kΩ or 50kΩ)

Note: Reference resistance is measurement range dependent.

Accuracy of V, I

Accuracy of V, I: ±(2% + |Z| accuracy)

Accuracy of |Z| and θ (1 year 18°-28°C)*

For 0.2Ω ≤ |Z| ≤ 20MΩ and 0.9-1.1V test level, see Table A-1.
For 0.2Ω ≤ |Z| ≤ 20MΩ and 50mV test level, see Table A-2.
For |Z| < 0.2Ω and 1V test level, see Table A-3.
For |Z| >20MΩ and 1V test level, see Table A-4.
*when properly zero corrected and using Model 3323A test fixture.

Specifications subject to change without notice.

Table A-1. Impedance Magnitude Accuracy (%) and Phase Accuracy (°)
Test Level= 0.9-1.1Vrms, Speed = Med or Slow

|Z| (Ω)	Frequency (Hz)								
	40 ~ 90	100 ~ 130	160 ~ 900	1k	1.1k ~ 5.0k	5.1k ~ 10k	11k ~ 20k	21k ~ 50k	51k ~ 100k
10M ≤ |Z| < 20M	4.5% 2.25°	3.0% 1.5°	2.0% 1.0°	1.0% 0.80°	2.0% 1.5°	3.5% 2.0°	4.0% 3.0°	14% 8.0°	20% 12°
5M ≤ |Z| < 10M	2.2% 1.3°	1.5% 0.90°	1.0% 0.60°	0.5% 0.40°	1.0% 0.60°	1.8% 1.1°	2.0% 1.3°	7.0% 4.0°	10% 6.0°
2M ≤ |Z| < 5M	1.10% 0.68°	0.75% 0.45°	0.5% 0.30°	0.3% 0.20°	0.5% 0.30°	0.9% 0.60°	1.0% 0.60°	3.5% 2.0°	5.0% 3.0°
1M ≤ |Z| < 2M	0.54% 0.33°	0.36% 0.22°	0.30% 0.15°	0.20% 0.10°	0.30% 0.15°	0.40% 0.20°	0.50% 0.30°	1.6% 1.0°	3.0% 2.0°
200k ≤ |Z| < 1M	0.37% 0.22°	0.25% 0.15°	0.20% 0.12°	0.15% 0.09°	0.20% 0.12°	0.27% 0.16°	0.35% 0.20°	1.0% 0.60°	2.0% 1.2°
20k ≤ |Z| < 200k	0.22% 0.15°	0.15% 0.10°	0.12% 0.06°	0.10% 0.04°	0.18% 0.08°	0.25% 0.15°	0.30% 0.20°	0.60% 0.40°	1.2% 0.8°
2k ≤ |Z| < 20k	0.21% 0.13°	0.14% 0.09°	0.12% 0.05°	0.10% 0.03°	0.12% 0.06°	0.15% 0.08°	0.20% 0.12°	0.40% 0.30°	0.80% 0.60°
10 ≤ |Z| < 2k	0.20% 0.12°	0.13% 0.08°	0.11% 0.05°	0.10% 0.03°	0.11% 0.08°	0.13% 0.10°	0.17% 0.15°	0.40% 0.25°	0.70% 0.50°
2 ≤ |Z| < 10	0.37% 0.22°	0.25% 0.15°	0.20% 0.10°	0.15% 0.07°	0.20% 0.12°	0.32% 0.20°	0.50% 0.30°	0.80% 0.40°	1.5% 0.80°
1 ≤ |Z| < 2	0.52% 0.33°	0.35% 0.22°	0.30% 0.20°	0.20% 0.12°	0.25% 0.15°	0.50% 0.30°	0.70% 0.40°	1.0% 0.60°	2.0% 1.2°
0.5 ≤ |Z| < 1	1.0% 0.68°	0.70% 0.45°	0.60% 0.40°	0.40% 0.25°	0.50% 0.30°	0.80% 0.50°	1.2% 0.70°	1.7% 1.0°	3.3% 2.0°
0.2 ≤ |Z| < 0.5	2.1% 1.3°	1.4% 0.90°	1.1% 0.70°	0.80% 0.50°	1.1% 0.70°	1.2% 0.80°	1.8% 1.1°	2.7% 1.6°	5.5% 3.0°

Notes:

1. For 5°C-18°C, or 28°C-40°C, multiply the |Z| accuracy by 1.4, and the phase accuracy by 1.8.
2. When measurement speed is FAST, multiply the accuracies by 2.0.
3. For test levels other than 0.9-1.1Vrms or 50mVrms see Accuracy Notes.

Table A-2. Impedance Magnitude Accuracy (%) and Phase Accuracy (°)
Level = 50mVrms, Speed = Med or Slow

|Z| (Ω)	Frequency (Hz)								
	40 ~ 90	100 ~ 130	160 ~ 900	1k	1.1k ~ 5.0k	5.1k ~ 10k	11k ~ 20k	21k ~ 50k	51k ~ 100k
10M ≤ |Z| < 20M	10.5% 6.0°	7.0% 4.0°	4.5% 2.5°	3.5% 2.0°	6.0% 3.5°	8.5% 5.0°	17% 10.0°	100% 60°	120% 70°
5M ≤ |Z| < 10M	5.25% 3.0°	3.5% 2.0°	2.2% 1.3°	1.7% 1.0°	2.7% 1.6°	3.5% 2.0°	7.0% 4.0°	50% 30°	60% 35°
2M ≤ |Z| < 5M	3.0% 1.8°	2.0% 1.2°	1.2% 0.80°	0.90% 0.60°	1.2% 0.8°	1.6% 1.0°	3.5% 2.0°	25% 15°	30% 18°
1M ≤ |Z| < 2M	1.5% 0.90°	1.0% 0.60°	0.60% 0.35°	0.40% 0.25°	0.60% 0.35°	0.80% 0.50°	1.6% 0.90°	12% 7.0°	14% 8.0°
200k ≤ |Z| < 1M	0.75% 0.45°	0.50% 0.30°	0.40% 0.25°	0.30% 0.18°	0.35% 0.20°	0.40% 0.25°	0.70% 0.40°	6.0% 3.6°	7.0% 4.0°
20k ≤ |Z| < 200k	0.45% 0.27°	0.30% 0.18°	0.20% 0.12°	0.16% 0.08°	0.24% 0.14°	0.32% 0.18°	0.40% 0.23°	1.8% 1.0°	3.0% 1.5°
2k ≤ |Z| < 20k	0.37% 0.23°	0.25% 0.15°	0.18% 0.09°	0.16% 0.06°	0.20% 0.12°	0.24% 0.14°	0.35% 0.20°	1.4% 0.80°	2.0% 1.2°
10 ≤ |Z| < 2k	0.30% 0.18°	0.20% 0.12°	0.18% 0.09°	0.15% 0.06°	0.20% 0.12°	0.23% 0.13°	0.32% 0.18°	1.2% 0.70°	1.6% 1.0°
2 ≤ |Z| < 10	0.75% 0.45°	0.50% 0.30°	0.35% 0.20°	0.25% 0.14°	0.35% 0.20°	0.50% 0.30°	0.70% 0.40°	3.4% 2.0°	4.0% 2.3°
1 ≤ |Z| < 2	1.5% 0.9°	1.0% 0.60°	0.60% 0.40°	0.50% 0.30°	0.60% 0.40°	0.80% 0.50°	1.1% 0.70°	6.0% 3.6°	8.0% 5.0°
0.5 ≤ |Z| < 1	2.7% 1.65°	1.8% 1.1°	1.2% 0.70°	1.0% 0.60°	1.2% 0.70°	1.5% 0.90°	1.8% 1.1°	10% 6.0°	14% 8.5°
0.2 ≤ |Z| < 0.5	5.55% 3.3°	3.7% 2.2°	2.6% 1.5°	2.0% 1.2°	2.6% 1.5°	2.9% 1.7°	3.4% 2.0°	21% 13°	28% 16°

Notes:

1. For 5°C-18°C, or 28°C-40°C, multiply the |Z| by 2.0, and the phase accuracy by 2.0.
2. When measurement speed is fast, multiply the accuracies by 2.0.
3. Accuracy is not guaranteed in the following ranges: |Z| > 20MΩ, |Z| < 0.2Ω.
4. For test levels other than 0.9-1.1Vrms or 50mVrms see Accuracy Notes.

Table A-3. Accuracy of |Z| and θ for |Z| <0.2Ω

|Z| (Ω)	LEVEL =1V rms, SPEED = MED or SLOW Frequency, (Hz)							
	100 120	200 500	1k	2k 5k	10k	20k	50k	100k
0≤|Z|<0.2	1.7% +0.2mΩ	1.5% +0.2mΩ	1.0% +0.2mΩ	1.3% +0.2mΩ	1.4% +0.3mΩ	2.0% +0.6mΩ	3.0% +1.5mΩ	6.0% +3mΩ

|Z| Accuracy: ±(% reading + R) shown.
θ Accuracy: (θ Accuracy for 0.2≤|Z|<0.5 in Table A-1) × (0.2Ω/|Z|)
When SPEED=FAST, multiply accuracy by 2.
For 5°-18°C or 28°-40°C, multiply accuracy by 2.

Table A-4. Accuracy of |Z| and θ for |Z|≥20MΩ

|Y| (S)	LEVEL =1V rms, SPEED = MED or SLOW Frequency, (Hz)							
	100 120	200 500	1k	2k 5k	10k	20k	50k	100k
0≤|Y|≤50nS	1.8nS	1.2nS	0.6nS	1.2nS	2.1nS	2.4nS	7.5nS	12nS

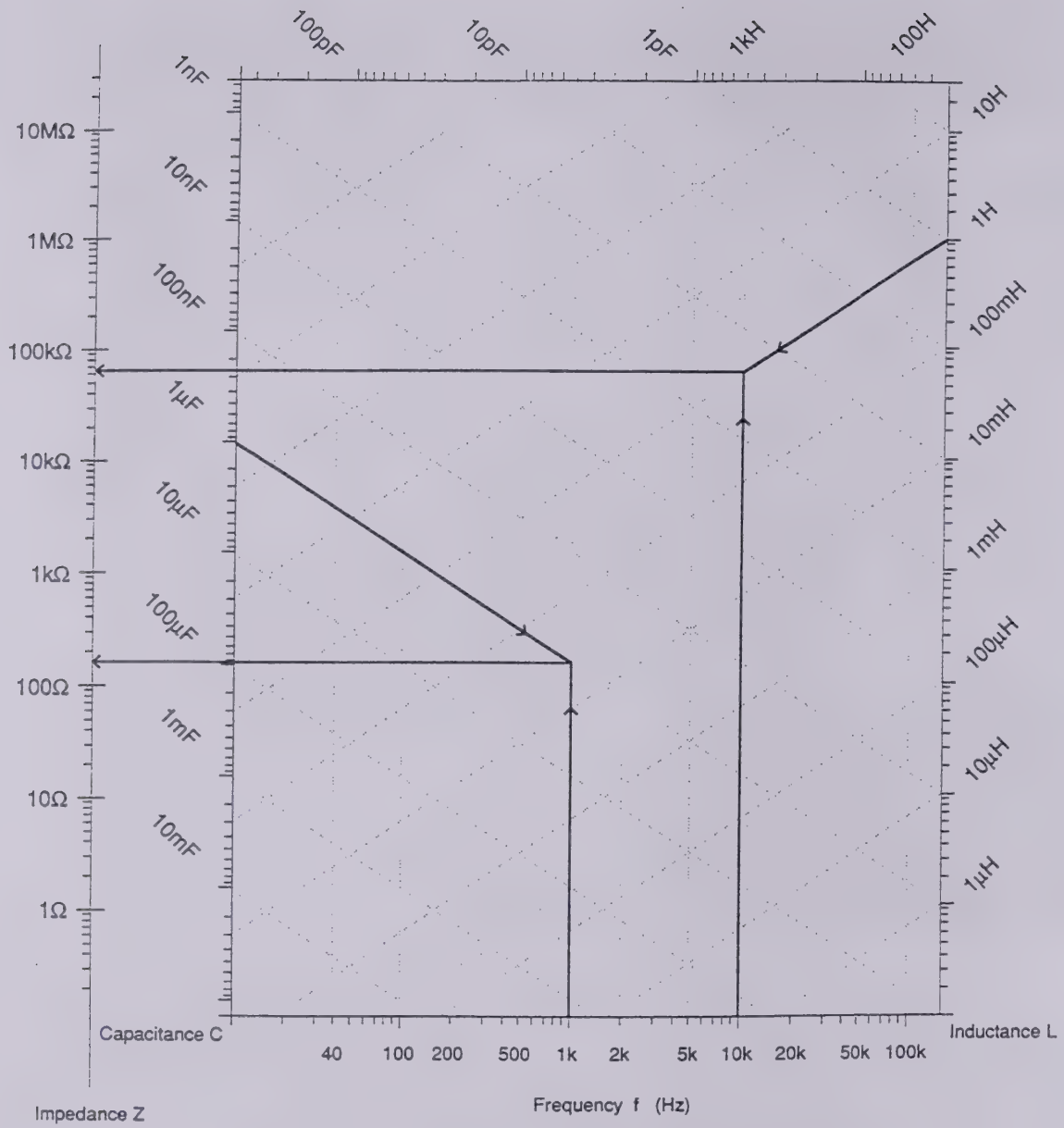
|Z| Accuracy: Specified by the ± deviation (S) of admittance |Y| shown.
θ Accuracy: (θ Accuracy for 10M≤|Z|<20M in Table A-1 × (|Z|/20MΩ).
When SPEED=FAST, multiply accuracy by 2.
For 5°-18°C or 28°-40°C, multiply accuracy by 2.

Accuracy Notes

1. When a measurement is made at line frequency or at twice line frequency, the measured value may deviate beyond the accuracy range due to interaction with line frequency. In this case, use 50Hz or 100Hz for a 60Hz line and 60Hz or 120Hz for a 50Hz line.
2. Tables A-1 through A-4 show the worst case value in each impedance range. A more precise value for accuracy may be obtained by interpolation.
3. In order to determine the impedance magnitude accuracy (A_Z) and impedance phase accuracy (A_θ) at measurement signal levels (LV) other than 50mV or 0.9V - 1.1V, use one of the following equations:

Measurement Signal Level (LV) From	To	Measured Impedance Magnitude |Z|	Impedance Magnitude Accuracy [%] (A_Z)	Impedance Phase Accuracy [°] (A_θ)
10mV	49mV	<20MΩ and ≥0.2Ω	$A_{Z2}\left(\frac{50mV}{LV}\right)$	$A_{\theta2}\left(\frac{50mV}{LV}\right)$
51mV	899mV	≥20MΩ	$A_{Z4}\left(\frac{1V}{LV}\right)$	$A_{\theta4}\left(\frac{1V}{LV}\right)$
51mV	899mV	<20MΩ and ≥0.2Ω	$A_{Z1}+\left[(A_{Z2}-A_{Z1})\left(\frac{50mV}{LV}\right)\right]$	$A_{\theta1}+\left[(A_{\theta2}-A_{\theta1})\left(\frac{50mV}{LV}\right)\right]$
51mV	899mV	<0.2Ω	$A_{Z3}\left[1+\left(\frac{100mV}{LV}\right)\right]\left(\frac{0.2\Omega}{\lvert Z\rvert}\right)[\%]+B_{Z3}\,[m\Omega]$	$A_{Z3}\,[\%]\times0.6°$

where:
LV = Test level voltage
A_{Z1} = Impedance Magnitude Accuracy (%) from Table A-1
$A_{\theta1}$ = Impedance Phase Accuracy (°) from Table A-1
A_{Z2} = Impedance Magnitude Accuracy (%) from Table A-2
$A_{\theta2}$ = Impedance Phase Accuracy (°) from Table A-2
A_{Z3} = Impedance Magnitude Accuracy (%) from Table A-3
B_{Z3} = Impedance Magnitude offset (mΩ) from Table A-3
A_{Z4} = Impedance Magnitude Accuracy (%) from Table A-4
$A_{\theta4}$ = Impedance Phase Accuracy (°) from Table A-4
A_{Z5} = Impedance Magnitude Accuracy for 51mV ≤ LV ≤ 899mV and $|Z| < 0.2\Omega$



Notes: Use this chart to determine the impedance magnitude of an inductor or capacitor at a particular frequency. For example, a 1H inductor at 10kHz and a 1µF capacitor at 1kHz are shown on the diagram.

1H @ 10kHz = 63kΩ
1µF @ 1kHz = 160Ω

Figure A-1. Conversion Diagram

Examples of Determining Accuracy

Example 1: Component = 33kΩ resistor
Test Frequency = 10kHz
Test Level = 1V rms
Temperature = 18°-28°C
Speed = Med or Slow

1. Find the accuracy values corresponding to 33kΩ and 10kHz on Table A-1. Record the impedance magnitude accuracy (0.25%) and impedance phase accuracy (0.15°).
2. If the ambient temperature is 5°C - 18°C or 28°C - 40°C, multiply the impedance magnitude accuracy by 1.4 and the impedance phase accuracy by 1.8.
3. If measurement speed is set to FAST, multiply the impedance magnitude accuracy by 2.0 and the impedance phase accuracy by 2.0.
4. Resistance accuracy is approximately equal to the impedance magnitude accuracy if $Q \leq 0.1$.
5. If $Q > 0.1$, see example 4.

Example 2: Component = 10μF capacitor
Test Frequency = 1kHz
Test Level = 50mV
Temperature = 18°-28°C
Speed = Med or Slow

1. Determine the impedance of the 10μF capacitor at 1kHz by referring to Figure A-1 or by solving the following equation:

$$|Z| = \frac{1}{2\pi fC} = \frac{1}{2\pi \times 1kHz \times 10\mu F} = 16\Omega$$

2. Find the accuracy values corresponding to 16Ω at 1kHz on Table A-2. Record the impedance magnitude accuracy (0.15%) and impedance phase accuracy (0.06°).
3. If the ambient temperature is 5°C - 18°C or 28°C - 40°C, multiply the impedance magnitude accuracy by 1.4 and the impedance phase accuracy by 1.8.
4. If measurement speed is set to FAST, multiply the impedance magnitude accuracy by 2.0 and the impedance phase accuracy by 2.0.
5. If $D \leq 0.1$, the accuracy of the capacitance measurement accuracy (C_{acc}) is related to the impedance magnitude accuracy (Z_{acc}) by the following equation:

$$C_{acc} = \frac{Z_{acc}}{1 - Z_{acc}}$$

In this example $Z_{acc} = 0.1\%$ and $C_{acc} = 0.1001\%$.

6. If $D > 0.1$, see example 4.

Example 3: Component = 680μH
Test Frequency = 100kHz
Test Level = 1V rms
Temperature = 18°-28°C
Speed = Med or Slow

1. Determine the impedance magnitude accuracy of the 680μH inductor at 100kHz by referring to Figure A-1 or by solving the following equation:

$$|Z| = 2\pi fL = 2\pi \times 100kHz \times 680\mu H = 427\Omega$$

2. Find the accuracy values corresponding to 427Ω at 100kHz on Table A-1. Record the impedance magnitude accuracy (0.7%) and impedance phase accuracy (0.5°).
3. If the ambient temperature is 5°C - 18°C or 28°C - 40°C, multiply the impedance magnitude accuracy by 1.4 and the impedance phase accuracy by 1.8.
4. If measurement speed is set to FAST, multiply the impedance magnitude accuracy by 2.0 and the impedance phase accuracy by 2.0.
5. If $Q > 10$ the inductance measurement accuracy is approximately equal to the impedance magnitude accuracy.
6. If $Q < 10$, see example 4.

Example 4: Determine precision of parameters other than $|Z|$ and θ at any frequency.

1. First, measure $|Z|$ and θ. Or, calculate them from other measured parameters by applying the following equations:

θ_{meas}	$= \arctan Q$	$Q = 1/D$
$\|Z\|_{meas}$	$= 2\pi fL_S/\sin\theta$	$= 2\pi fL_S/ESR$
	$= 1/(2\pi fC_S \sin\theta)$	$= 1/(2\pi fC_S\ ESR)$
	$= 2\pi fL_P \sin\theta$	$= (2\pi fC_P)/G$
	$= \sin\theta/(2\pi fC_P)$	$= 1/(2\pi fL_P\ G)$

where:
f = frequency (Hz).
C_S, L_S = series equivalent circuit variables.
C_P, L_P = parallel equivalent circuit variables.

2. Determine the impedance magnitude accuracy (A_Z) and impedance phase accuracy (A_θ) of $|Z_{meas}|$ and θ_{meas} by referring to the appropriate table (Table A-1, A-2, A-3 or A-4).
3. Determine the maximum and minimum value by using the following equations:

$Z_{max} = |Z|_{meas} \times (1 + A_Z)$
$Z_{min} = |Z|_{meas} \times (1 - A_Z)$
$\theta_{max} = \theta_{meas} + A_\theta$
$\theta_{min} = \theta_{meas} - A_\theta$

4. Determine the maximum and minimum value of the parameter of interest by substituting the values found in step 3 into one of the following equations. There will be four combinations:

R_S	$= \|Z\| \cos\theta$	R_P	$= \|Z\|/\cos\theta$
ESR	$= \|Z\| \cos\theta$	G	$= \cos\theta/\|Z\|$
X	$= \|Z\| \sin\theta$	B	$= \sin\theta/\|Z\|$
L_S	$= X/2\pi f$	L_P	$= -1/2\pi fB$
C_S	$= -1/2\pi fX$	C_P	$= B/2\pi f$
Q	$= \|\tan\theta\|$	D	$= 1/\|\tan\theta\|$

5. Accuracy is found by determining the largest deviation from the measured values.

A.2 MEASUREMENT SIGNAL

Frequency

Range:
40Hz-130Hz: 10Hz steps
160, 200, 250Hz
300Hz-9.9kHz: 100Hz steps
10kHz-100kHz: 1kHz steps
Accuracy: ±0.005%

Output Impedance: 100Ω (typ)

Signal Level (voltage when drive terminal HCUR is open)

Range: 10mVrms-1.100Vrms: 1mV steps
Accuracy:
±(3% + 1mV) for 1kHz
±(4% + 1mV) for 40Hz-20kHz
±(5% + 1mV) for 21kHz-100kHz)

Bias Voltage

Internal: 0 or +2VDC (±5%)
External: 0 to ±35VDC

A.3 COMPARATOR/BINNING FUNCTIONS

Number of bins: 20.

The comparator function can sort on the main parameters (R, L, C, or Z) into bins 1-19. Also, the comparator function can sort on the sub-parameter into bin 0 (Q, D, ESR, G or X).

A.4 FRONT PANEL SET-UP MEMORY

Number of front panel set-ups: 10.

Front panel set-up contents: All front panel parameters except bias control.

Battery life: At least 3 years if storage temperture is less than 40°C.

A.5 HANDLER INTERFACE

Connector: 36-pin Centronics type (Cinch 57-30360)

Output signals:

BIN 0-11:	Bin judgment signals
A_NG:	Main parameter failure
B_NG:	Sub-parameter failure
STROBE:	Judgment completion pulse (pulse width ≥1.5ms)
BUSY:	Measurement in progress flag

Output characteristics:
Type: TTL negative logic
Maximum TTL load: 10 standard TTL
Maximum output current: 48mA (sink, output voltage ≤1V)

Input signals:
TRIG: Measurement start trigger (pulse width ≥100µs)
LOCK: Panel operation prohibited

Input characteristics:
Low level input voltage: -1.5 to +0.8V
High level input voltage: +2.4V to 30V (TRIG), +3.5V to 30V (LOCK)
Low level input current (Approximation)
TRIG: -0.33mA
LOCK: -3mA

Handler Interface Ground: isolated from chassis ground. Max voltage from chassis ±42VDC.

Beeper (two functions, dip switch selectable):
Beeper on/off: Enables beeper function.
Beeper Mode:
1. Beep only for NO GO
2. 4KHz beep for GO and 2kHz beep for NO GO.

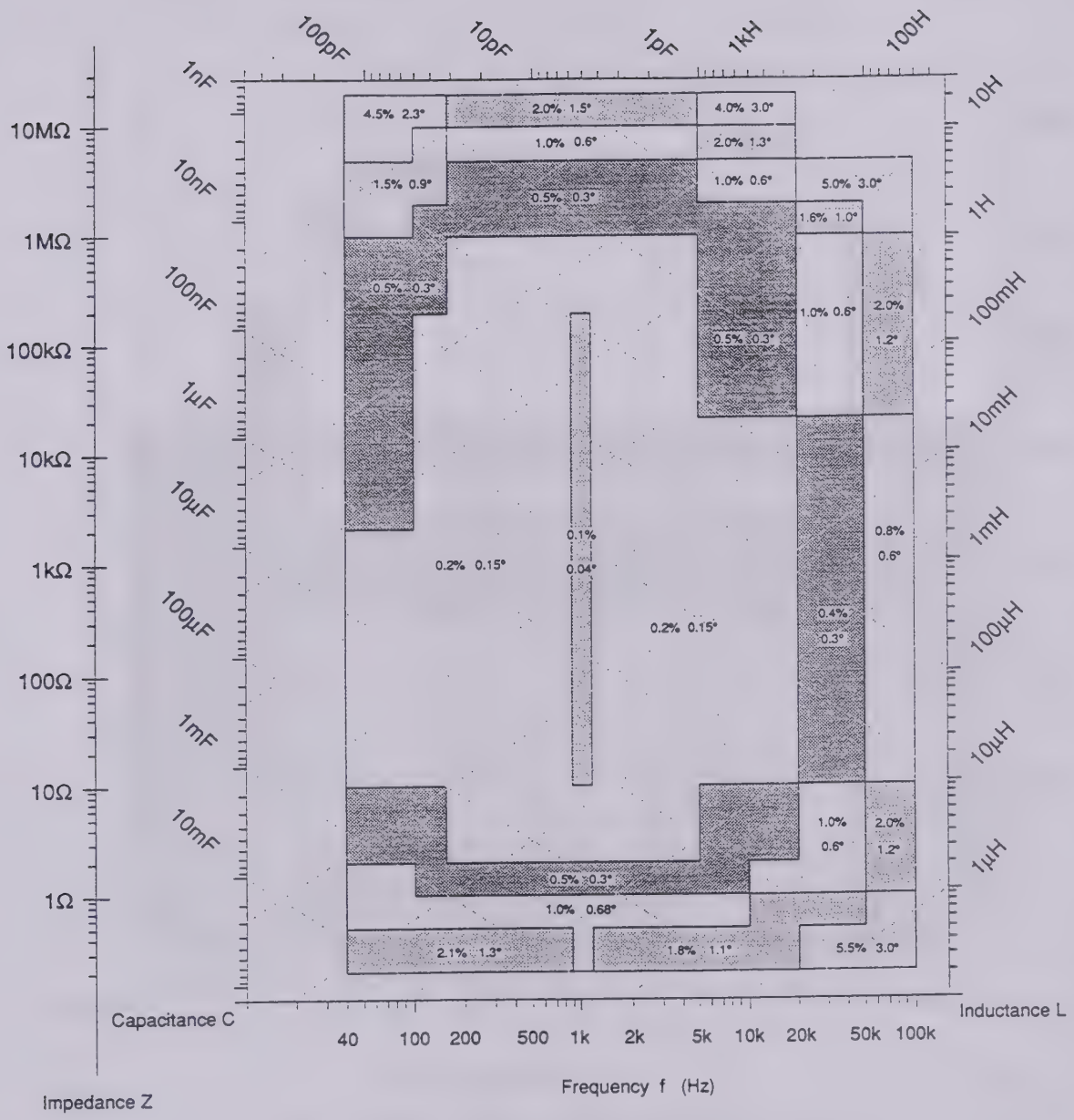
Note: GO refers to comparator bins 1-19, and NO GO refers to comparator bin 0.

A.6 IEEE-488 BUS IMPLEMENTATION

Multiline Commands: DCL, SDC, GET, GTL, UNT, UNL, SPE, SPD
Uniline Commands: IFC, REN, EOI, SRQ, ATN
Interface Functions: SH1, AH1, T5, L4, SR1, RL2, PP0, DC1, DT1, C0.

A.7 GENERAL

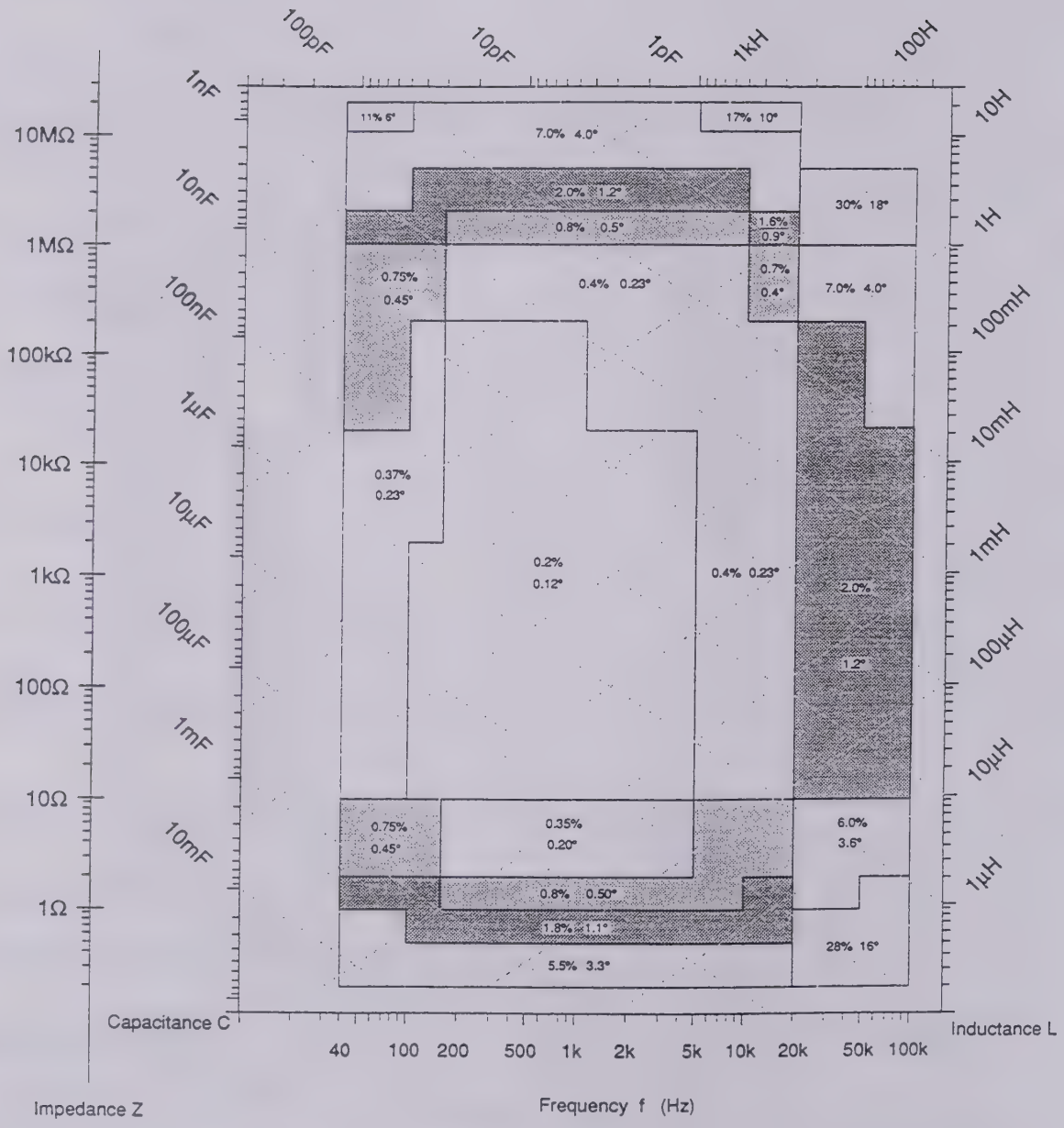
Line Voltage: 100, 120, 220 or 240 ±10% VAC (external switch selectable)
Environment: Operating: 0°~40°C, 10~90% RH (non-condensing)
Storage: -10°~50°C, 10~80% RH (non-condensing)
Dimensions, Weight: 132.5mm high × 216mm wide × 350mm deep (5 ¼ in. × 8 ½ in. × 13 ¾ in.) Net weigth 3.7kg (8.1 lbs.) (instrument only, excluding accessories).
Warm-up: 30 minutes.
Front Panel Connectors: 4 BNC connectors and a five way binding post.
Rear Panel Connectors:
Handler Interface
External Bias: BNC
IEEE Connector: Floating
Display: Two 4 ½ digit displays for main and sub-parameters.
Trigger Mode: Automatic (continuous) and manual.
Trigger Delay Time: 0-199.99s
Calibration Cycle: 1 year



Note : 1. For 5°C-18°C, or 28°C-40°C, multiply the |Z| accuracy by 1.4, and the phase accuracy by 1.8.
2. When measurement speed is FAST, double the accuracy.

Level = 0.9V-1.1V rms Speed = Medium or Slow

Figure A-2. Accuracy Diagram



Note : 1. For 5°C-18°C, or 28°C-40°C, multiply the |Z| accuracy by 2.0, and the phase accuracy by 2.0.
2. When measurement speed is FAST, double the accuracy.
3. Accuracy is not guaranteed in the following ranges : |Z|>20MΩ, |Z|<.2Ω.

Level = 50mV rms Speed = Medium or Slow

Figure A-3. Accuracy Diagram

Model 3330
LCZ Meter

Service Manual

Contains Servicing Information

KEITHLEY

WARRANTY

Keithley Instruments, Inc. warrants this product to be free from defects in material and workmanship for a period of 1 year from date of shipment.

Keithley Instruments, Inc. warrants the following items for 90 days from the date of shipment: probes, cables, rechargeable batteries, diskettes, and documentation.

During the warranty period, we will, at our option, either repair or replace any product that proves to be defective.

To exercise this warranty, write or call your local Keithley representative, or contact Keithley headquarters in Cleveland, Ohio. You will be given prompt assistance and return instructions. Send the product, transportation prepaid, to the indicated service facility. Repairs will be made and the product returned, transportation prepaid. Repaired or replaced products are warranted for the balance of the original warranty period, or at least 90 days.

LIMITATION OF WARRANTY

This warranty does not apply to defects resulting from product modification without Keithley's express written consent, or misuse of any product or part. This warranty also does not apply to fuses, software, non-rechargeable batteries, damage from battery leakage, or problems arising from normal wear or failure to follow instructions.

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Model 3330 LCZ Meter
Service Manual

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Test Instrumentation Group
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Safety Precautions

The following safety precautions should be observed before using the Model 3330 LCZ Meter and any associated instruments.

This instrument is intended for use by qualified personnel who recognize shock hazards and are familiar with the safety precautions required to avoid possible injury. Read over this manual carefully before using the instrument.

Exercise extreme caution when a shock hazard is present at the test circuit. The American National Standards Institute (ANSI) states that a shock hazard exists when voltage levels greater than 30V rms or 42.4V peak are present. **A good safety practice is to expect that hazardous voltage is present in any unknown circuit before measuring.**

Inspect the connecting cables and test leads for possible wear, cracks, or breaks before each use.

For maximum safety, do not touch the test cables or any instruments while power is applied to the circuit under test. Turn off the power and discharge any capacitors before connecting or disconnecting cables from the instrument.

Do not touch any object which could provide a current path to the common side of the circuit under test or power line (earth) ground. Always make measurements with dry hands while standing on a dry, insulated surface capable of withstanding the voltage being measured.

Instrumentation and accessories should not be connected to humans.

HOW TO USE THIS MANUAL

Details procedures to verify that the instrument meets stated specifications.

SECTION 1
Performance Verification

Describes basic operating principles for the various circuits in the Model 3330.

SECTION 2
Principles of Operation

Covers fuse replacement, calibration and repair of the instrument, and lists replacement parts.

SECTION 3
Service Information

WARNING

The information in this manual is intended for qualified service personnel who can recognize possible shock hazards. Do not attempt these procedures unless you are qualified to do so.

Table of Contents

SECTION 1 — Performance Verification

1.1 INTRODUCTION 1-1
1.2 INITIAL CONDITIONS 1-1
1.3 LINE POWER 1-1
1.4 VERIFICATION LIMITS 1-1
1.5 MEASUREMENT SIGNAL TESTS 1-2
1.5.1 Environmental Conditions 1-2
1.5.2 Recommended Test Equipment 1-2
1.5.3 Frequency Accuracy 1-3
1.5.4 Measurement Signal Level Accuracy 1-3
1.5.5 Measurement Signal Distortion 1-4
1.5.6 Output Impedance Accuracy 1-4
1.5.7 Internal Bias Voltage Accuracy 1-6
1.5.8 External DC Bias Voltage Range 1-6
1.6 MEASUREMENT ACCURACY TESTS 1-7
1.6.1 Environmental Conditions 1-7
1.6.2 Recommended Equipment 1-7
1.6.3 Recommended Standards Accuracy 1-7
1.6.4 Resistance Measurement Accuracy 1-8
1.6.5 Capacitance Reading Checks 1-11
1.6.6 Inductance Reading Checks 1-11

SECTION 2 — Principles of Operation

2.1 INTRODUCTION 2-1
2.2 BLOCK DIAGRAMS 2-1
2.3 CURRENT AND VOLTAGE DETECTION 2-1
2.4 IMPEDANCE CALCULATION 2-1
2.5 OSCILLATOR 2-4
2.6 CURRENT-TO-VOLTAGE CONVERTER 2-5
2.7 ANALYZER 2-5

SECTION 3 — Service Information

3.1 INTRODUCTION 3-1
3.2 FUSE REPLACEMENT 3-1
3.2.1 Line Fuse 3-1
3.2.2 External Bias Fuse 3-1
3.3 CALIBRATION 3-1
3.4 FAN FILTER CLEANING 3-2
3.5 REPAIR 3-2
3.5.1 Factory Service 3-2

3.5.2 Cover Removal 3-2
3.5.3 Battery Replacement 3-2
3.5.4 Operation Check Procedure 3-4
3.5.5 Repair Summary 3-4
3.6 REPLACEABLE PARTS 3-5
3.6.1 Parts List 3-5
3.6.2 Ordering Parts 3-5

APPENDICES

A Specifications

List of Tables

SECTION 1 — Performance Verification

Table 1-1	Recommended Test Equipment for Measurement Signal Tests	1-2
Table 1-2	Distortion Measurement Summary	1-4
Table 1-3	Recommended Equipment for Measurement Accuracy Tests	1-8
Table 1-4	Resistance Measurement Accuracy Reading Limits (|Z|) for 1Vrms Level	1-9
Table 1-5	Resistance Measurement Accuracy Reading Limits (θ) for 1Vrms Level	3-10
Table 1-6	Resistance Measurement Accuracy Reading Limits (|Z|) for 50Vrms Level	3-10
Table 1-7	Resistance Measurement Accuracy Reading Limits (θ) for 50Vrms Level	3-10

SECTION 3 — Service Information

Table 3-1	Recommended Line Fuse	3-1
Table 3-2	Self-calibration Errors	3-4
Table 3-3	Operation Check Problem Summary	3-4
Table 3-4	Measurement Signal Problem Summary	3-5
Table 3-5	Model 3330 Replaceable Parts	3-6

List of Illustrations

SECTION 1 — Performance Verification

Figure 1-1 Connections for Measurement and Signal Level Accuracy 1-3
Figure 1-2 Connections for Frequency Accuracy Measurement 1-4
Figure 1-3 Connections for Distortion Measurements 1-5
Figure 1-4 Connections for Output Impedance Tests 1-5
Figure 1-5 Connections for DC Bias Accuracy Tests 1-6
Figure 1-6 Connections for External DC Bias Voltage Range Test 1-7
Figure 1-7 Connections for Resistance Accuracy Measurements 1-9
Figure 1-8 Connections for Capacitance and Inductance Reading Checks 1-12

SECTION 2 — Principles of Operation

Figure 2-1 Measuring System Block Diagram 2-2
Figure 2-2 Hardware Block Diagram 2-3
Figure 2-3 Oscillator Block Diagram 2-4
Figure 2-4 Current-to-Voltage Converter 2-5
Figure 2-5 Analyzer 2-6

SECTION 3 — Service Information

Figure 3-1 Cover Removal 3-3
Figure 3-2 Model 3330 Exploded View 3-7

SECTION 1
Performance Verification

1.1 INTRODUCTION

The procedures outlined in this section may be used to verify that the Model 3330 LCZ Meter is operating within limits stated in the specifications. Performance verification may be done when the instrument is first received to ensure that no damage or misadjustment has occurred during shipment. Verification may also be performed whenever there is a question of instrument accuracy.

NOTE

If instrument performance is outside the specified range, and the instrument is still under warranty, contact your Keithley representative or the factory to determine the correct course of action.

Performance verification falls into the following two general categories:

- Measurement signal tests (paragraph 1.5)
- Measurement accuracy and reading checks (paragraph 1.6)

1.2 INITIAL CONDITIONS

The Model 3330 should be turned on and allowed to warm up for at least one-half hour before performing the verification procedures. (The test equipment should also be allowed to warm up for the time period recommended by the manufacturer.) If the instrument has been subjected to extreme temperature or humidity, allow additional time for internal circuits to reach normal operating temperature. Typically, it takes one additional hour to stabilize a unit that is 10°C (18°F) outside the specified temperature range.

1.3 LINE POWER

Be sure to set the line voltage switch on the rear panel to the correct line voltage. The instrument should be tested while operating on a line voltage within ±5% of the line voltage switch setting and at a line frequency from 48Hz to 62Hz.

1.4 VERIFICATION LIMITS

The performance verification limits stated in this section reflect only the accuracy specifications of the Model 3330. They do not include test equipment tolerance.

1.5 MEASUREMENT SIGNAL TESTS

Measurement signal tests measure various characteristics of the test signal that is applied to the DUT. These tests include:

- Frequency accuracy
- Measurement signal level accuracy
- Measurement signal distortion
- Output impedance accuracy
- Internal DC bias voltage accuracy
- External DC bias voltage range

1.5.1 Environmental Conditions

All measurement signal tests should be performed at an ambient temperature of 23° ± 5°C and at a relative humidity of 50% ± 30%.

1.5.2 Recommended Test Equipment

Table 1-1 lists the test equipment required to perform the measurement signal tests. The procedures for measurement signal verification tests are based on using this exact equipment. Alternate equipment may be used as long as that equipment has specifications at least good as those stated in Table 1-1.

Table 1-1. Recommended Test Equipment for Measurement Signal Tests

Manufacturer	Model	Description	Specifications
Keithley	197A	DMM (AC volts, DC volts, 5-1/2 digits)	2VDC range; ±(0.011% of rdg + 2 counts) 2VAC range; ±(0.35% of rdg + 100 counts)
Philips	PM 6654C PM 9678	Timer/counter TCXO option	0.01Hz-120MHz; time base aging $<1 \times 10^{-7}$/month
Panasonic	VP-7722A	Audio analyzer DC power supply	10Hz-110kHz; 0.01% accuracy at full scale; ±1dB harmonic distortion accuracy from 10Hz to 15.99kHz 0-40VDC adjustable, <5mVp-p ripple
Keithley	1681	Test leads	Two leads terminated with banana plug and clip-on probes
Keithley	7051-2	BNC interconnect cable	50Ω coaxial cable (RG-58C), male BNC connectors, 2ft. (0.6m)
Keithley	7754-3	BNC to alligator cable	Coaxial cable, male BNC connector, two alligator clips
Keithley	3324	Test leads	4-terminal alligator clip test lead set
Keithley	3325	Test leads	Kelvin clip test lead set
Pomona	1468	BNC-banana adapter Capacitor Resistor Switch	Female BNC connector to double banana plug 10µF, 100VDC 100Ω ±0.5%, 1/2W Single-pole, single-throw

1.5.3 Frequency Accuracy

1. Connect the Model 3330 H CUR jack to input A of the counter/timer, as shown in Figure 1-1. Be sure to connect the G terminal of the LCZ meter to the shield of the connecting cable as shown.
2. Set the LCZ meter operating modes as follows:

   FREQ: 1kHz
   LEVEL: 1Vrms
   BIAS: OFF

3. Set the counter/timer to measure frequency on input A.
4. Verify that the counter reading is between 0.999950kHz and 1.000050kHz (±50ppm).

1.5.4 Measurement Signal Level Accuracy

1. Connect the Model 3330 H CUR jack to the DMM, as shown in Figure 1-2. Be sure to connect the G terminal of the LCZ meter to the shield of the connecting cable as shown.
2. Select the ACV function and auto-ranging on the DMM.
3. Set the LCZ meter operating modes as follows:

   LEVEL: 1Vrms
   FREQ: 1kHz
   BIAS: OFF

4. Verify that the DMM reading is between the limits for 1Vrms, 1kHz operation, as follows:

   0.97Vrms to 1.03Vrms (±3.0%).

5. Change the LEVEL to 50mVrms, and verify the signal level accuracy for 1kHz , 50mVrms operation is as follows:

   47.5mVrms to 52.5mVrms (±5.0%)

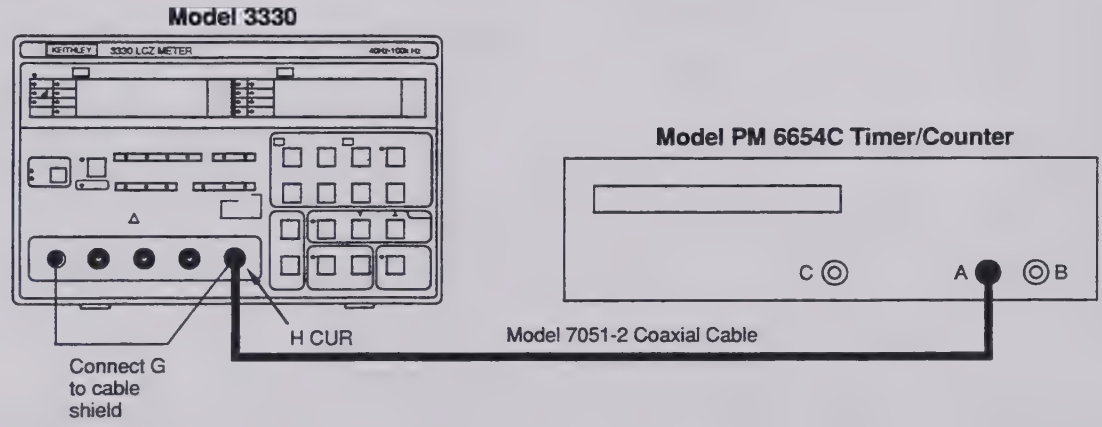


Figure 1-1. Connections for Measurement and Signal Level Accuracy

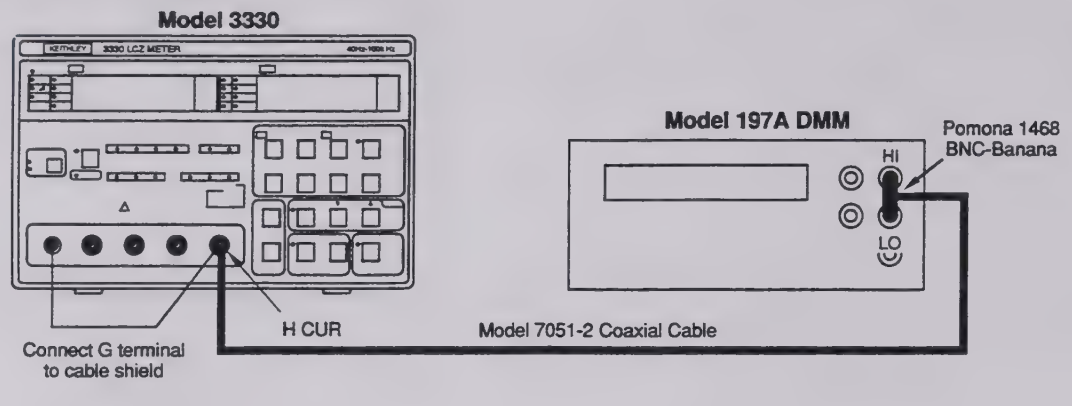


Figure 1-2. Connections for Frequency Accuracy Measurement

1.5.5 Measurement Signal Distortion

1. Connect the H CUR jack of the LCZ meter to the distortion meter, as shown in Figure 1-3. Be sure to connect the G terminal of the LCZ meter to the cable shield as shown.
2. Set the LCZ meter operating modes as follows:

   LEVEL: 1Vrms
   BIAS: OFF
   FREQ: 1kHz

3. Verify that the distortion reading is 0.3% or less, as summarized in Table 1-2.

Table 1-2. Distortion Measurement Summary

Frequency	Distortion Reading
200Hz	≤ 0.3%
1kHz	≤ 0.3%
100kHz	≤ 0.5%

4. Change the frequency to 100kHz.
5. Verify that the distortion reading is 0.5% or less.
6. Set the Model 3330 frequency to 200Hz as follows:
   A. Press the SETUP key to enter the auxiliary setup mode. The LED above the FREQ (HZ) marking blinks, and the unit displays the present frequency in the [B] DISPLAY area.
   B. Enter a frequency of 200Hz.
   C. Press the ENTER/EXIT key twice to complete 200Hz programming.
7. Verify that the distortion reading is 0.3% or less.

1.5.6 Output Impedance Accuracy

1. Connect the LCZ meter to the DMM, switch, and resistor, as shown in Figure 1-4. Be sure that the G terminal of the LCZ meter is connected to the cable shield, and that the resistor and switch are connected as shown.
2. Select the 2VAC range on the DMM.
3. Set the LCZ meter operating modes as follows:

   FREQ: 1kHz
   LEVEL: 1Vrms
   BIAS: OFF

4. Set the switch to the open position, then note the DMM reading. Call this reading V_1.
5. Set the switch to the closed position, then note the DMM reading. Call this reading V_2.
6. Compute the output impedance from V_1 and V_2 as follows:

   $Z_{OUT} = 100\ (V_1/V_2 - 1)\ [\Omega]$

7. Verify that the output impedance computed in step 6 is between 97Ω and 103Ω inclusive (±3%).

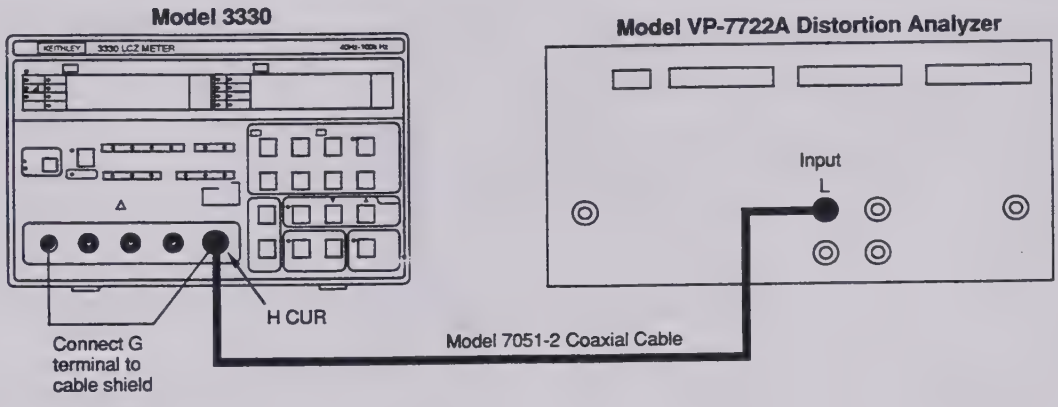


Figure 1-3. Connections for Distortion Measurements

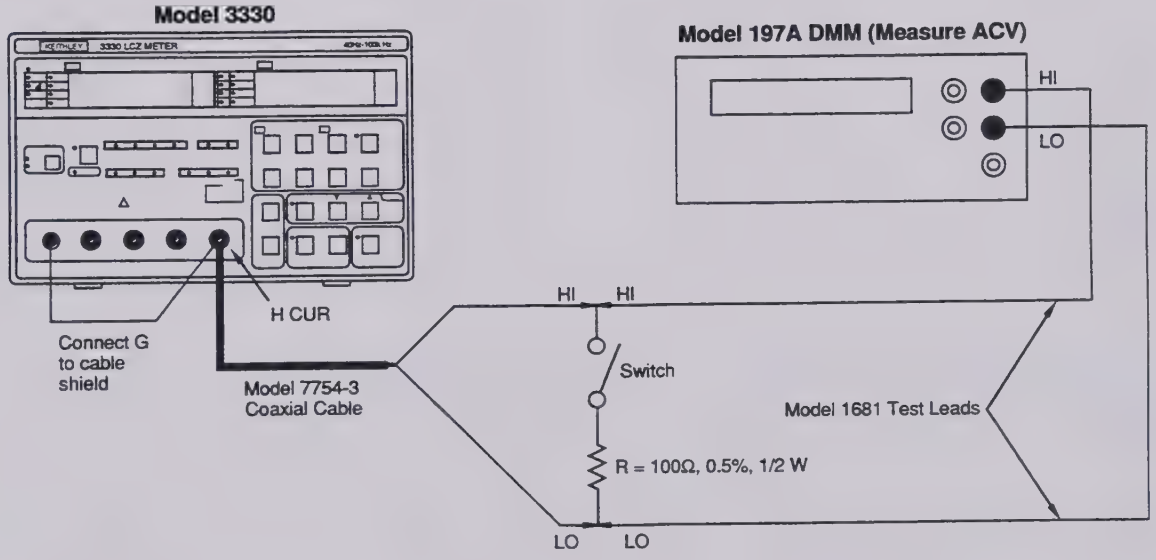


Figure 1-4. Connections for Output Impedance Tests

1.5.7 Internal Bias Voltage Accuracy

1. Connect the LCZ meter to the DMM using the Model 3324 cables (see Figure 1-5). Note that connections are intended to measure the voltage between the H CUR and L CUR terminals.
2. Select the 2VDC range on the DMM.
3. Set the LCZ meter operating modes as follows:

   [A] DISPLAY: C
   LEVEL: 50mVrms
   RANGE: AUTO
   BIAS INT/EXT: INT (rear panel switch)
   BIAS: ON

4. Verify that the DMM reading is between 1.9V and 2.1V inclusive (±5%).
5. Set the LCZ meter to BIAS OFF.
6. Select the 200mVDC range on the DMM.
7. Verify that the DMM reading is 0V ±10mV.

1.5.8 External DC Bias Voltage Range

1. Connect the LCZ meter to the DC power supply, capacitor, and DMM, as shown in Figure 1-6.
2. Select the DCV function and auto-ranging on the DMM.
3. Set LCZ meter operating modes as follows:

   [A] DISPLAY: C
   FREQ: 120Hz
   LEVEL: 50mVrms
   BIAS INT/EXT: EXT (rear panel switch)
   BIAS: OFF

4. Set the unit to RANGE 2 as follows:
   A. Measure the value of the 10µF capacitor in the RANGE AUTO mode (DC BIAS OFF).
   B. Verify that the Model 3330 is properly measuring the capacitor.
   C. Press the RANGE/AUTO key, and check that the AUTO LED goes off. The unit is now set to RANGE 2.
5. Check the voltage across the capacitor with BIAS OFF, and with BIAS ON and a 35V external bias voltage setting on the DC power supply (35V must be available with BIAS ON).
6. Disconnect the DMM, and measure the capacitor value. Verify that the reading is stable to within ±2 digits of the center value (four digits of span).

WARNING
Hazardous voltage (>30V) will be used in the following steps. Do not touch the capacitor until the test is complete, and the capacitor is discharged.

7. Set the unit to BIAS OFF, and set the external DC power supply voltage to +40V.
8. Set the LCZ meter to BIAS ON, and verify that the BIAS fuse does not blow.
9. Set the unit to BIAS OFF, then turn off and disconnect the external DC power supply.

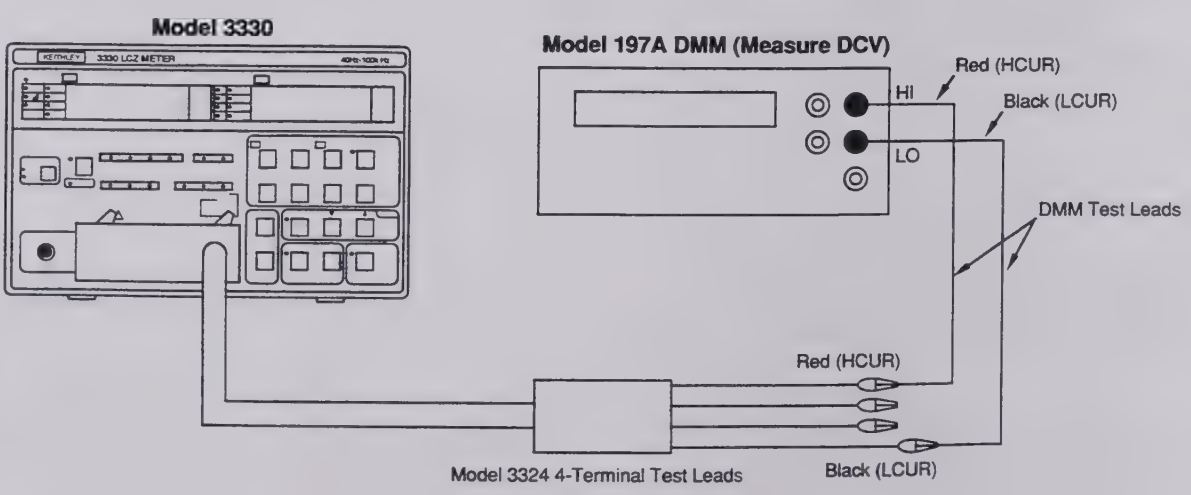


Figure 1-5. Connections for DC Bias Accuracy Tests

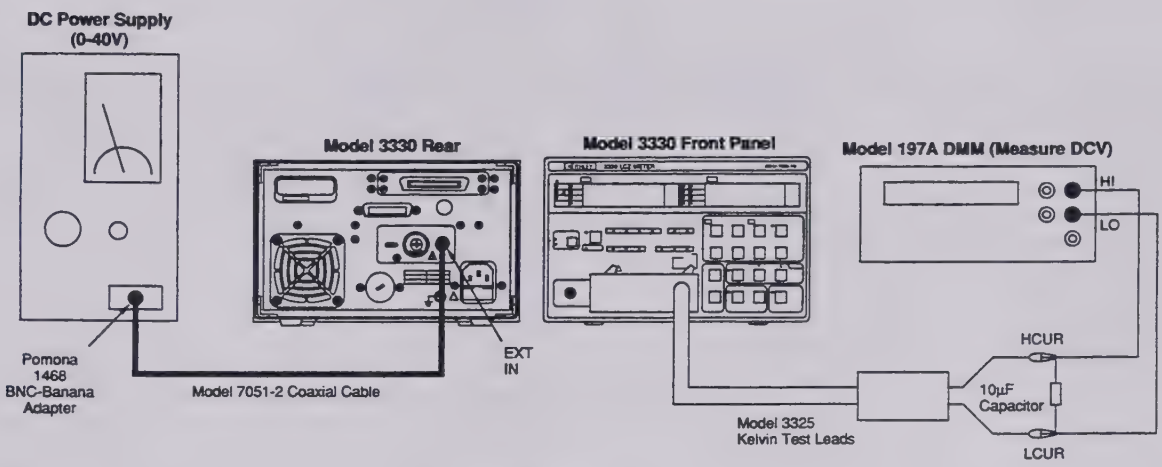


Figure 1-6. Connections for External DC Bias Voltage Range Test

1.6 MEASUREMENT ACCURACY TESTS

Measurement accuracy tests include:

- R (resistance) measurement accuracy
- C (capacitance) reading checks
- L (inductance) reading checks

1.6.1 Environmental Conditions

All resistance measurement accuracy tests should be performed at an ambient temperature of 23° ± 1°C and at a relative humidity of 50% ± 20%. Capacitance and inductance reading checks can be performed at 23° ± 5°C.

1.6.2 Recommended Equipment

Table 1-3 lists the resistance standards, capacitors, inductors, and additional equipment required to perform the measurement accuracy tests. The procedures for resistance measurement accuracy verification tests are based on using these standards. Listed capacitors and inductors are to be used to perform capacitance and inductance reading checks that are not based on instrument accuracy specifications.

NOTE

The Model 3330 makes all measurements based on the magnitude and phase of the impedance of the DUT connected to the UNKNOWN terminals. For that reason, verification of resistance measurement accuracy is sufficient to guarantee the accuracy of capacitance and inductance measurements. The resistance standards values used are the same as those used for calibration. Capacitance and inductance reading checks are included to verify that the instrument properly displays capacitance and inductance values.

1.6.3 Resistance Standards Accuracy

Resistance standards used for the measurement accuracy tests should be calibrated at certain intervals so as to ensure the accuracy of standards values. Standards accuracy tolerances should be added to the stated measurement limits.

1.6.4 Resistance Measurement Accuracy

Resistance accuracy measurements are made using the resistance standards listed in Table 1-3 and the test connections shown in Figure 1-7.

NOTE

Be sure to connect the H and L terminals of the resistance standards to the H and L terminals respectively of the LCZ meter, or inaccurate measurements may result. Do not handle the standards excessively, or the resulting temperature rise may affect their values.

Procedure:

1. Set the Model 3330 operating modes as follows:

   [A] DISPLAY: |Z|
   [B] DISPLAY: θ
   FREQ: 40Hz
   LEVEL: 1Vrms
   SPEED: MED
   RANGE: AUTO

2. Connect the OPEN resistance standard to the instrument, then press ZERO OPEN. Allow the instrument to complete the zero cycle before proceeding.
3. Connect the SHORT resistance standard to the instrument, then press ZERO SHORT. Allow the instrument to complete the zero cycle before proceeding.
4. Connect the 100Ω resistance standard to the instrument, and allow the reading to settle.
5. Verify that the |Z| and θ readings are within the limits shown in Table 1-4 and Table 1-5 respectively.
6. Repeat steps 4 and 5 for the remaining standards values listed in the table (1kΩ through 100kΩ), and verify that all readings are within the required limits.
7. Repeat steps 2 through 6 for the remaining frequencies listed in the tables.
8. Change the LEVEL to 50mVrms, then repeat steps 2 through 7 for the frequencies summarized in Table 1-6 and Table 1-7.

Table 1-3. Recommended Equipment for Measurement Accuracy Tests

Description	Manufacturer/Model	Values
Resistance standards	Hewlett-Packard HP 16074A Calibration Standard	OPEN, SHORT, 100Ω, 1 kΩ, 10kΩ, 100kΩ
Capacitors	User supplied	100pF, 0.01μF, ±1%
Inductors	User supplied	100μH, 10mH, ±1%
Test Fixture*	Keithley 3323	

*Fixture used to connect capacitors and inductors.

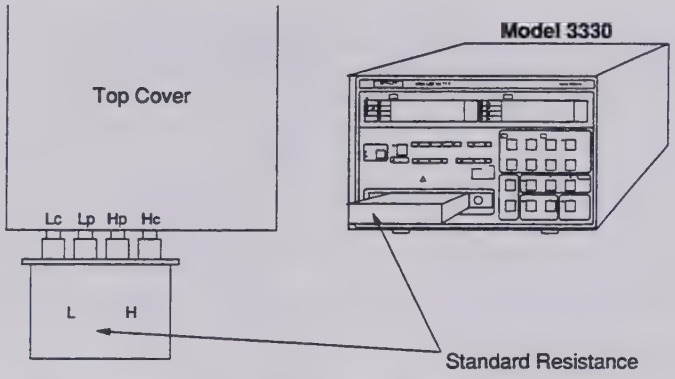


Figure 1-7. Connections for Resistance Accuracy Measurements

Table 1-4. Resistance Measurement Accuracy Reading Limits (|Z|) for 1Vrms Level

Resistance Standard Value	|Z| Reading Limits at Indicated Frequency (Hz)								
	40	120	500	1k	5k	10k	20k	50k	100k
100Ω	99.80 to 100.20Ω	99.87 to 100.13Ω	99.89 to 100.11Ω	99.90 to 100.10Ω	99.89 to 100.11Ω	99.87 to 100.13Ω	99.83 to 100.17Ω	99.60 to 100.40Ω	99.30 to 100.70Ω
1kΩ	0.9980 to 1.0020kΩ	0.9987 to 1.0013kΩ	0.9988 to 1.0012kΩ	0.9990 to 1.0010kΩ	0.9989 to 1.0011kΩ	0.9987 to 1.0013kΩ	0.9983 to 1.0017kΩ	0.9960 to 1.0040kΩ	0.9930 to 1.0070kΩ
10kΩ	9.979 to 10.021kΩ	9.986 to 10.014kΩ	9.988 to 10.012kΩ	9.990 to 10.010kΩ	9.988 to 10.012kΩ	9.985 to 10.015kΩ	9.980 to 10.020kΩ	9.960 to 10.040kΩ	9.920 to 10.080kΩ
100kΩ	99.78 to 100.22kΩ	99.85 to 100.150kΩ	99.88 to 100.12kΩ	99.90 to 100.100kΩ	99.82 to 100.18kΩ	99.75 to 100.25kΩ	99.70 to 100.30kΩ	99.40 to 100.60kΩ	98.80 to 101.20kΩ

NOTE: Limits shown do not include resistance standards tolerances. All measurements to be made at 23°±1°C

Table 1-5. Resistance Measurement Accuracy Reading Limits (θ) for 1Vrms Level

Resistance Standard Value	θ Reading Limits at Indicated Frequency (Hz)								
	40	120	500	1k	5k	10k	20k	50k	100k
100Ω	0° ± 0.12°	0° ± 0.08°	0° ± 0.05°	0° ± 0.03°	0° ± 0.08°	0° ± 0.10°	0° ± 0.15°	0° ± 0.25°	0° ± 0.50°
1kΩ	0° ± 0.12°	0° ± 0.08°	0° ± 0.05°	0° ± 0.03°	0° ± 0.08°	0° ± 0.10°	0° ± 0.15°	0° ± 0.25°	0° ± 0.50°
10kΩ	0° ± 0.13°	0° ± 0.09°	0° ± 0.05°	0° ± 0.03°	0° ± 0.06°	0° ± 0.08°	0° ± 0.12°	0° ± 0.30°	0° ± 0.60°
100kΩ	0° ± 0.15°	0° ± 0.10°	0° ± 0.06°	0° ± 0.04°	0° ± 0.08°	0° ± 0.15°	0° ± 0.20°	0° ± 0.40°	0° ± 0.80°

NOTE: Measurements should be made at 23°±1°C.

Table 1-6. Resistance Measurement Accuracy Reading Limits (\| Z \|) for 50Vrms Level

Resistance Standard Value	| Z | Reading Limits at Indicated Frequency (Hz)								
	40	120	500	1k	5k	10k	20k	50k	100k
100Ω	99.70 to 100.30Ω	99.80 to 100.20Ω	99.82 to 100.18Ω	99.85 to 100.15Ω	99.80 to 100.20Ω	99.77 to 100.23Ω	99.68 to 100.32Ω	98.80 to 101.20Ω	98.40 to 101.60Ω
1kΩ	0.9970 to 1.0030kΩ	0.9980 to 1.0020kΩ	0.9982 to 1.0018kΩ	0.9985 to 1.0015kΩ	0.9980 to 1.0020kΩ	0.9977 to 1.0023kΩ	0.9968 to 1.0032kΩ	0.9880 to 1.0120kΩ	0.9840 to 1.0160kΩ
10kΩ	9.963 to 10.037kΩ	9.975 to 10.025kΩ	9.982 to 10.018kΩ	9.984 to 10.016kΩ	9.980 to 10.020kΩ	9.976 to 10.024kΩ	9.965 to 10.035kΩ	9.860 to 10.140kΩ	9.800 to 10.200kΩ
100kΩ	99.55 to 100.45kΩ	99.70 to 100.30kΩ	99.80 to 100.20kΩ	99.84 to 100.16kΩ	99.76 to 100.24kΩ	99.68 to 100.32kΩ	99.60 to 100.40kΩ	98.20 to 101.80kΩ	97.00 to 103.00kΩ

NOTE: Limits shown do not include resistance standards tolerances. All measurements to be made at 23°±1°C

Table 1-7. Resistance Measurement Accuracy Reading Limits (θ) for 50Vrms Level

Resistance Standard Value	θ Reading Limits at Indicated Frequency (Hz)								
	40	120	500	1k	5k	10k	20k	50k	100k
100Ω	0° ± 0.18°	0° ± 0.12°	0° ± 0.09°	0° ± 0.06°	0° ± 0.12°	0° ± 0.13°	0° ± 0.18°	0° ± 0.70°	0° ± 1.0°
1kΩ	0° ± 0.18°	0° ± 0.12°	0° ± 0.09°	0° ± 0.06°	0° ± 0.12°	0° ± 0.13°	0° ± 0.18°	0° ± 0.70°	0° ± 1.0°
10kΩ	0° ± 0.23°	0° ± 0.15°	0° ± 0.09°	0° ± 0.06°	0° ± 0.12°	0° ± 0.14°	0° ± 0.20°	0° ± 0.80°	0° ± 1.2°
100kΩ	0° ± 0.27°	0° ± 0.18°	0° ± 0.12°	0° ± 0.08°	0° ± 0.14°	0° ± 0.18°	0° ± 0.23°	0° ± 1.0°	0° ± 1.5°

NOTE: Readings should be taken at 23°±1°C

1.6.5 Capacitance Reading Checks

Capacitance reading checks are made using the 100pF and 0.01µF capacitors summarized in Table 1-3.

NOTE
The capacitance reading check procedure is not based on instrument accuracy specifications and is included only to show that the instrument properly displays capacitance readings. As noted previously, verification of resistance measurement accuracy is sufficient to verify capacitance measurement accuracy.

Procedure:

1. Set the Model 3330 operating modes as follows:

   [A] DISPLAY: C
   [B] DISPLAY: D
   CKT MODE: SER
   FREQ: 1kHz
   LEVEL: 1Vrms
   SPEED: MED
   RANGE: AUTO

2. Connect the Model 3323 Direct Test Fixture to the unit (Figure 1-8), but do not connect the capacitor to the test fixture at this time.
3. Short the test fixture terminals by connecting a bare wire between them. Press ZERO SHORT, and allow the instrument to complete the zero cycle. Remove the shorting wire after the zero cycle is completed.
4. Press ZERO OPEN, and allow the instrument to complete the zero cycle.
5. Connect the 100pF, ±1% capacitor to the test fixture terminals, and verify that the capacitance reading is within ±2% of 100pF (98pF to 102pF).
6. Connect the 0.01µF, ±1% capacitor to the test fixture terminals, and verify that the capacitance reading is within ±2% of 10nF (9.8nF to 10.2nF).

1.6.6 Inductance Reading Checks

Inductance reading checks are made using the 100µH and 10mH inductors summarized in Table 1-3.

NOTE
The inductance reading check procedure is not based on instrument accuracy specifications and is included only to show that the instrument properly displays inductance readings. As noted previously, verification of resistance measurement accuracy is sufficient to verify inductance measurement accuracy.

Procedure:

1. Set the Model 3330 operating modes as follows:

   [A] DISPLAY: L
   [B] DISPLAY: Q
   CKT MODE: SER
   FREQ: 1kHz
   LEVEL: 1Vrms
   SPEED: MED
   RANGE: AUTO

2. Connect the Model 3323 Direct Test Fixture to the unit (Figure 1-8), but do not connect the inductor to the test fixture at this time.
3. Short the test fixture terminals by connecting a bare wire between them. Press ZERO SHORT, and allow the instrument to complete the zero cycle. Remove the shorting wire after the zero cycle is completed.
4. Press ZERO OPEN, and allow the instrument to complete the zero cycle.
5. Connect the 100µH, ±1% inductor to the test fixture terminals, and verify that the inductance reading is within ±2% of 100µH (98µH to 102µH).
6. Connect the 10mH, ±1% inductor to the test fixture terminals, and verify that the inductance reading is within ±2% of 10mH (9.8mH to 10.2mH).

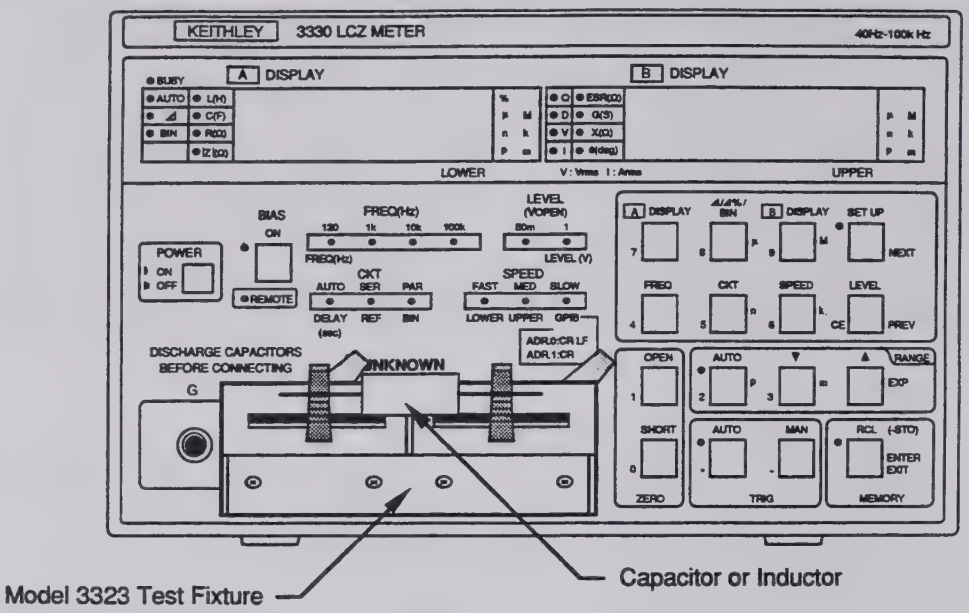


Figure 1-8. Connections for Capacitance and Inductance Reading Checks

SECTION 2
Principles of Operation

2.1 INTRODUCTION

This section discusses basic circuit operating principles for the Model 3330 LCZ Meter.

2.2 BLOCK DIAGRAMS

Figure 2-1 shows a block diagram of the measuring system, and Figure 2-2 is a hardware block diagram.

2.3 CURRENT AND VOLTAGE DETECTION

The instrument drives the device under test (DUT) with a signal from the built-in oscillator, and it detects the current I flowing through the DUT and the voltage E_V across the DUT. The current is converted to a voltage E_I by the operational amplifier and the reference resistor R_R.

Both AC signals E_V and E_I are converted into digital data by the A/D converter. The microprocessor then multiplies these signals by the reference sine wave and integrates the resultant signal digitally to obtain the voltage and current vectors (magnitude and phase) with respect to the reference oscillator signal. Using this method, it is possible to measure only the fundamental oscillator frequency component, minimizing the effects of distortion and noise.

2.4 IMPEDANCE CALCULATION

Impedance is calculated by dividing the voltage vector by the current vector. As a result, impedance is expressed as the ratio of the magnitudes and the differences in phase between the two vectors. Any current-to-voltage conversion errors are corrected based on factors determined when the instrument is calibrated. In addition, true impedance ($Z=R_S + jX$) is obtained by correcting residual impedance Z_{SS} and floating admittance Y_{PP}, and the instrument automatically calculates main and auxiliary parameters from R_S and X.

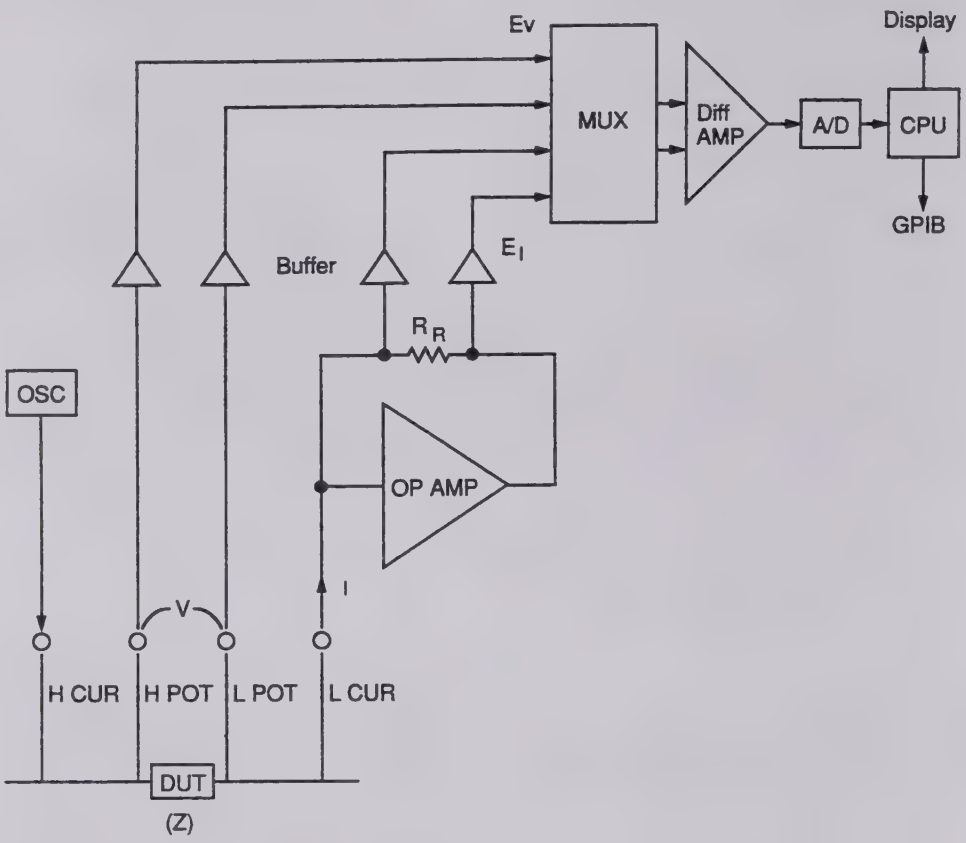


Figure 2-1. Measuring System Block Diagram

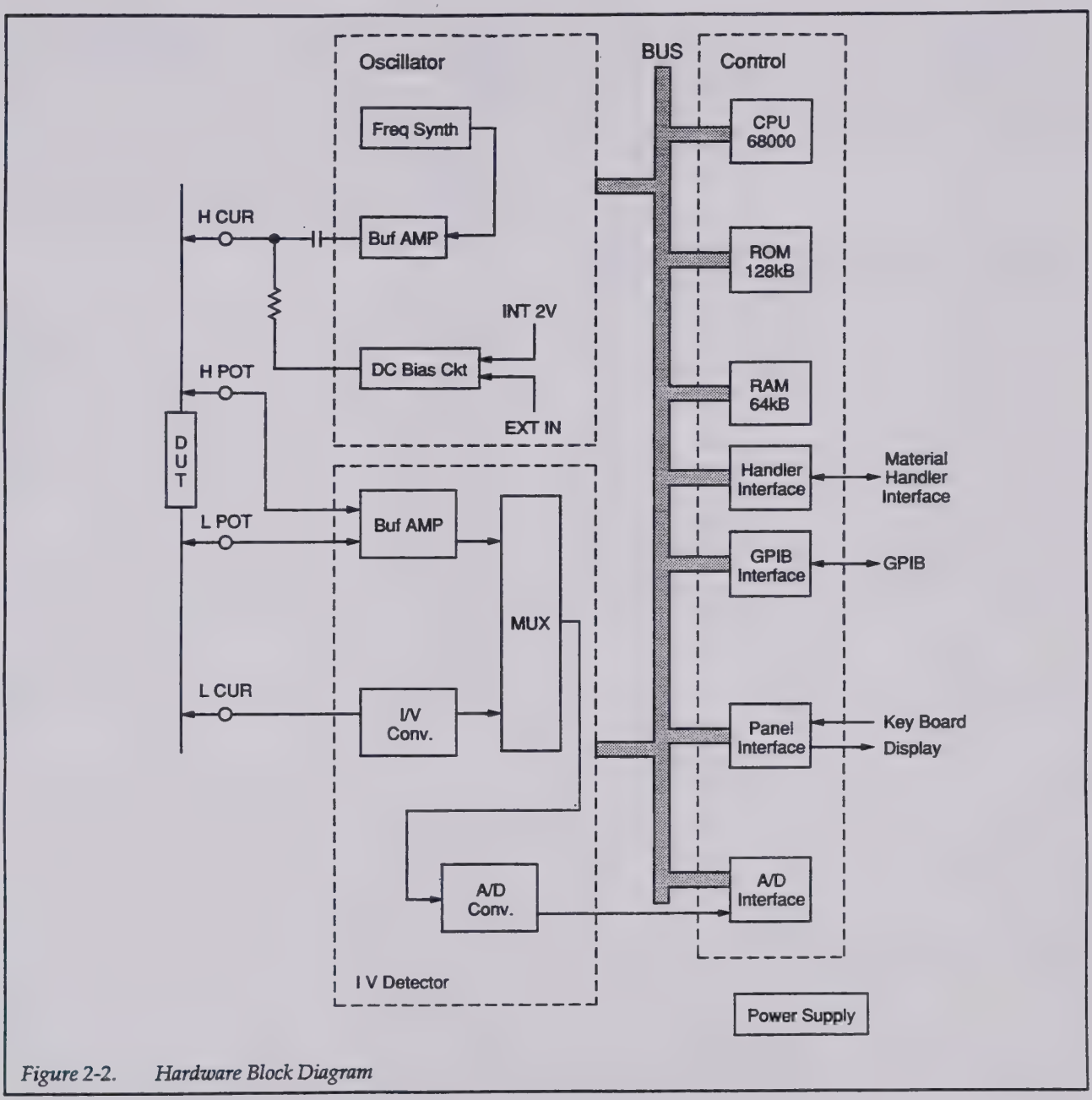


Figure 2-2. Hardware Block Diagram

2.5 OSCILLATOR

The oscillator (Figure 2-3) is a digital direct synthesis type frequency synthesizer, which uses a quartz oscillator to generate the reference frequency. The quartz oscillator is used to ensure that the synthesizer output remains stable.

The synthesizer output, which is a digital ramp signal, is converted into a sine wave by the sine ROM and is then converted into an analog signal by the D/A converter. Since the D/A converter output includes harmonics of the desired fundamental frequency, the D/A converter output signal is routed through the low-pass filter to obtain a pure sine wave.

The output of the oscillator is fed to the HCUR terminal to be applied to the DUT along with the DC bias voltage. The equivalent output impedance is approximately 100Ω.

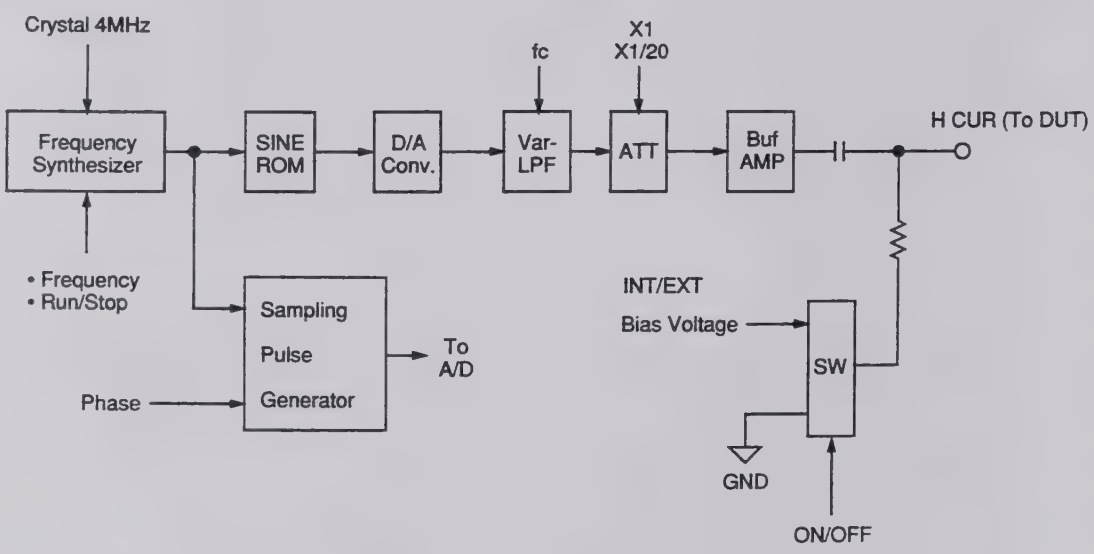


Figure 2-3. Oscillator Block Diagram

2.6 CURRENT-TO-VOLTAGE CONVERTER

The signal current from the DUT is converted to a voltage before measurement, a function performed by the current-to-voltage converter (Figure 2-4). The converter is made up of a high-gain operational amplifier and a reference resistor R_R, which forms the feedback loop for the op amp.

Since the operational amplifier has very high gain, its inverting input is at virtual ground potential. Consequently, the current flowing through Y_P can be neglected, and the signal current I has the same magnitude as the current flowing through R_R. As a result, the voltage across R_R, which is the same as the output voltage V_{OUT}, is simply IR_R. Note that the value of R_R can be changed according to the value of the DUT being measured in order to increase the dynamic range of the instrument.

At higher frequencies, the gain of the operational amplifier decreases, and the value of the floating admittance (which is made up primarily of capacitance at higher frequencies) increases. Consequently, the current to ground increases substantially, increasing the measurement error. The error term is proportional to the product of R_R and the square of the frequency.

2.7 ANALYZER

To eliminate the effects of a common-mode signal, the voltages (E_V and E_I) across the DUT and R_R are amplified by a differential amplifier and then routed to the A/D converter through a signal conditioner consisting of amplifiers and a low-pass filter (Figure 2-5). The low-pass filter attenuates any unwanted frequency components to prevent possible measurement errors.

The variable-gain amplifiers (AMP ×1 and AMP ×8) are used to increase the resolution of the 16-bit A/D converter when the voltage and current are small. The gain-phase characteristics are measured at power-on and in zero-measurement (OPEN and SHORT) modes, and the compensating factors are applied to subsequent impedance measurements to ensure that amplifier characteristics do not affect measurement accuracy.

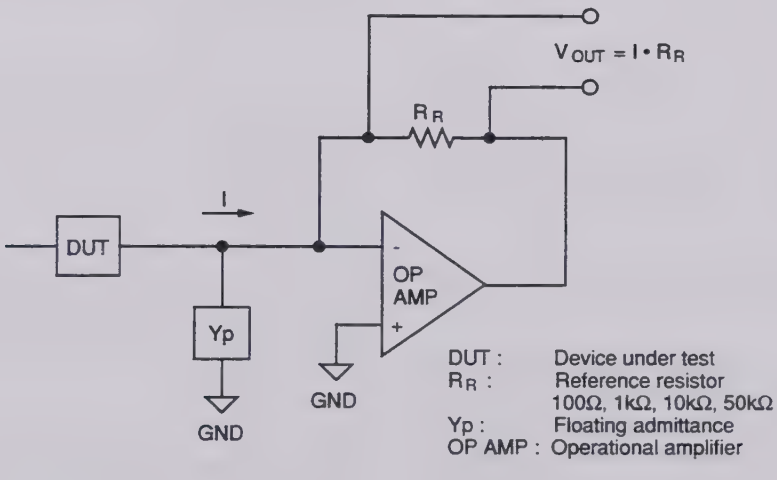


Figure 2-4. Current-to-Voltage Converter

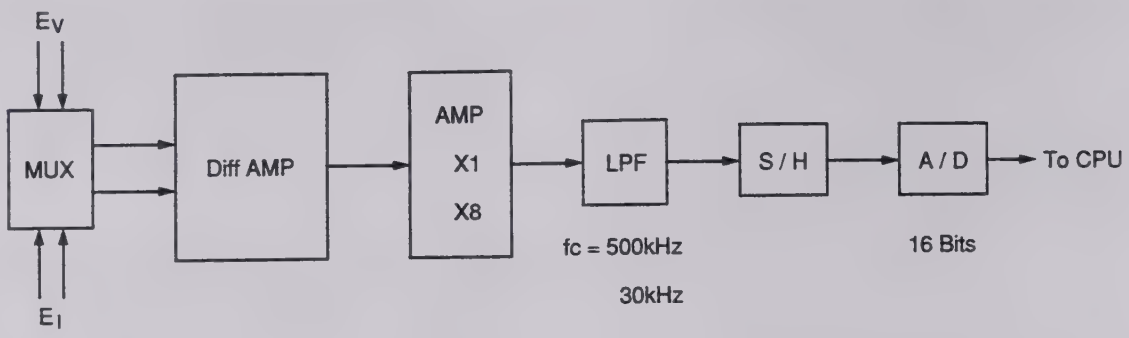


Figure 2-5. Analyzer

SECTION 3
Service Information

3.1 INTRODUCTION

This section contains information on fuse replacement, instrument repair, and replacement parts for the Model 3330.

3.2 FUSE REPLACEMENT

The following paragraphs discuss replacement of the line fuse and external bias fuse.

WARNING

Disconnect the line cord and all other equipment from the instrument before replacing fuses.

CAUTION

Using the wrong fuse type may result in instrument damage.

3.2.1 Line Fuse

The line fuse, which is located on the rear panel, protects the power line input from excessive current. To replace the fuse, first unplug the line cord, then pry out the fuse holder from the bottom of the line power receptacle. Replace the fuse only with the type recommended in Table 3-1.

Table 3-1. Recommended Line Fuses

Line Voltage	Description
100V/120V	1/2A, 250V, slow blow, 5mm × 20mm
220V/240V	1/4A, 250V, slow blow, 5mm × 20mm

3.2.2 External Bias Fuse

The external bias fuse protects the instrument from excessive current supplied by an external DC bias source. To replace this fuse, simply unscrew the fuse holder, then replace with the following type: 0.1A, 250V, fast blow, 5mm × 20mm.

3.3 CALIBRATION

Model 3330 calibration requires a special computer program, which is included with a calibration kit along with complete calibration instructions. Calibration kits are available free of charge from the factory. Please call 1-800-552-1115 to obtain your calibration kit.

3.4 FAN FILTER CLEANING

The fan filter should be cleaned at least once every three months when the unit is operated in a clean environment, or at least once a month when the unit is operated in a dirty environment. The fan filter element should be cleaned as follows:

1. Turn off instrument power, and disconnect the line cord.
2. Pry out the filter cover on the rear panel.
3. Remove the filter element.
4. Soak the filter element in a solution of mild detergent and water until clean.
5. Rinse the filter element thoroughly in clean water, then allow the filter to dry thoroughly before replacement.
6. When the filter has dried completely, install the filter and cover.

CAUTION

The instrument should not be operated without the filter in place.

3.5 REPAIR

3.5.1 Factory Service

If the Model 3330 is still under warranty, it is recommended that the unit be returned to the factory or a Keithley authorized repair facility for calibration or repair. When returning the unit for service, include the following:

- Call the Instruments Division Repair Department at 1-800-552-1115 for a Return Material Authorization (RMA) number.
- Write the RMA number and the following on the shipping label: ATTENTION REPAIR DEPARTMENT.
- Complete the service form at the back of this manual.
- Advise as to the warranty status of the instrument.

3.5.2 Cover Removal

The covers must be removed for repair. Follow the steps below to remove the covers using Figure 3-1 as a guide.

WARNING

Disconnect the line cord and all other equipment from the Model 3330 before removing the covers.

CAUTION

A conductive coating is applied to the inner surfaces of the covers. Be careful not to scratch the coating when removing covers. Also be careful not to peel off the plastic film on the front panel.

1. Place the instrument upside down on a soft cloth or rubber mat to avoid scratching the top cover.
2. Remove the four screws that secure the bottom cover, then remove the cover.
3. Place the instrument right side up.
4. Remove the top cover by separating it from the chassis.

3.5.3 Battery Replacement

The battery, which backs up setup and calibration constants RAM, should last for at least three years. If you notice the instrument no longer stores setups, the battery should be replaced. (A calibration error during the self-test may also indicate a discharged battery.) Follow the steps below to replace the battery.

CAUTION

Many parts on the internal circuit boards are static sensitive. To avoid possible damage, perform any repair operations only at a properly grounded work station, and use only grounded-tip soldering irons and anti-static de-soldering tools.

Replacement of lithium batteries is normally a safe procedure as long as the following safety precautions are followed:

WARNING

The precautions below must be followed to avoid possible personal injury.

1. **Wear safety glasses or goggles when working with lithium batteries.**
2. **Do not short the battery terminals together.**
3. **Do not incinerate or otherwise expose lithium batteries to excessive heat (>60°C).**

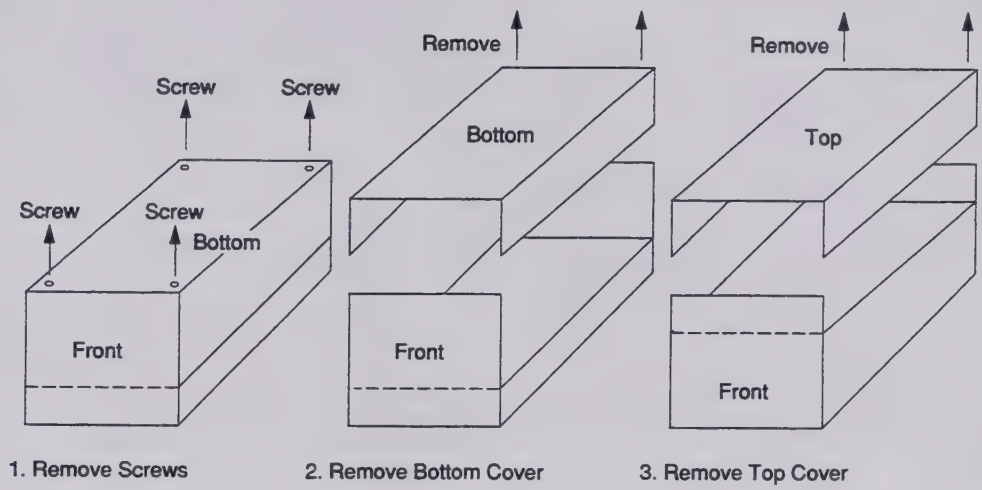


Figure 3-1. Cover Removal

4. **Keep lithium batteries away from all liquids.**
5. **Do not attempt to charge lithium batteries.**
6. **Observe proper polarity when installing lithium batteries.**

NOTE

Calibration constants are stored in battery backed up RAM. Model 3330 calibration will be required if the battery becomes fully discharged, or if you remove the battery.

1. Disconnect the line cord and all other instruments from the Model 3330.
2. Remove the top and bottom covers.
3. Note the positions of the various cables connected to the circuit board, then disconnect all cables from the board.
4. Remove the screws that secure the circuit board to the chassis.
5. Remove the control board.
6. Unsolder the battery terminals, and remove the battery.
7. Install a new battery, taking care to observe polarity.
8. Install the circuit board, and connect all cables to the board.
9. Replace the covers.
10. Calibrate the instrument after replacing the battery (see paragraph 3.3).

3.5.4 Operation Check Procedure

1. Connect the instrument to an appropriate power source using the supplied power cord.
2. Press in on the front panel POWER switch to turn on the power.
3. Verify that the instrument displays the ROM version number on the [A] DISPLAY area.
4. The instrument will then perform internal circuit checks and enter the self-calibration mode. During self-calibration, "CAL" is displayed on the [A] DISPLAY, and a decrementing number is displayed on the [B] DISPLAY section.
5. The number on the [B] DISPLAY section decrements; the self-calibration cycle ends when this number reaches zero.
6. If an error occurs, an appropriate message will be displayed (see Table 3-2). Turn the instrument off for three seconds, then turn power back on to see if the error clears. If the error persists and cannot be cleared, the instrument requires the indicated service.

3.5.5 Repair Summary

Table 3-3 summarizes the most likely source of the problem for the various operation check item problems (see paragraph 3.5.4). Table 3-4 summarizes actions to take for various measurement signal problems. (See Section 1 for measurement signal measurements.)

Table 3-2. Self-calibration Errors

Error Message	Description	Recommended Action
Err	Circuit abnormality	Repair instrument
Err EEEEE 22222	Invalid cal constants	Calibrate instrument
EEEEE 44444-77777	RAM error	Check RAM
EEEEE 99999	ROM error	Check ROM

Table 3-3. Operation Check Problem Summary

Problem	Action
Non-resettable error (except IEEEE 22222)	Replace RAM, ROM, or circuit board (NP-10420).
Resettable error	Reset error, and proceed with operation.
IEEEE 22222 error	Repeat test, calibrate unit if problem persists.*
Calibration error	Replace main board (NP-10420).
Front panel keys and/or LEDs do not function	Replace front panel circuit board.
Handler interface does not function	Replace handler interface board (NP-21127).

*If the calibration error persists, the internal battery may require replacement.

Table 3-4. Measurement Signal Problem Summary

Problem	Action
Frequency accuracy	Replace main board (NP-10420).
Measurement signal level	Perform calibration (replace main board if calibration is not effective).
Measurement signal distortion	Replace main board.
Output impedance accuracy	Replace main board.
Internal DC bias accuracy	Replace main board.
External DC bias voltage range	Replace main board.

3.6 REPLACEABLE PARTS

3.6.1 Parts List

Table 3-5 summarizes available Model 3330 replacement parts, and Figure 3-2 shows the location of mechanical parts.

3.6.2 Ordering Parts

To order a part, or to obtain information on replacement parts, contact your Keithley representative or the factory. When ordering parts, include the following information:

- Instrument model number
- Instrument serial number
- Keithley part number
- Part description

Table 3-5. Model 3330 Replaceable Parts

Description	Part Number	Quantity
FRONT PANEL SECTION		
Front panel	400-12310-00 506-00516-00	1*
Power switch (Front)	332-19133-00	1
Button	359-03554-00	1
Switch holder 1	526-12996-00	1
BNC connector (BNC137)	310-00169-00	4
Ground terminal	330-05346-00	1
REAR PANEL SECTION		
Rear panel	400-12328-00	1
Noise filter (inlet)	240-03212-00	1
Ground terminal	330-05389-00	1
Voltage selection switch	332-50057-00	1
Fan (DC12V, 60 × 60mm)	300-00785-00	1
Air filter	459-00205-00	1
Flat head screw (M3×40mm)	600-01241-00	4
Grommet (small)	546-00138-00	1
BNC connector (BNC137)	310-00169-00	1
Fuse holder	302-04045-00	1
Hex. stud (L=25)	606-00250-00	2
CHASSIS SECTION		
Chassis	516-07107-00	1
Hex. stud (L=8)	606-00080-00	6
Power switch	332-19141-00	1
Switch holder 2	526-13003-00	1
Flexible wire	332-19150-00	1
Power transformer (D: 432768)	244-10870-00	1
BOARD ASSEMBLY		
NP-10457 (MAIN)	080-33072-00	1
NP-21101A-1 (KEY)	080-33099-00	1**
NP-21101A-2 (BIAS)	080-33099-00	1**
NP-21127 (HANDLER I/F)	080-33510-00	1

* The front panel has two code numbers, and it is necessary to specify these two numbers when the front panel is ordered.

** These two boards combined into one set.

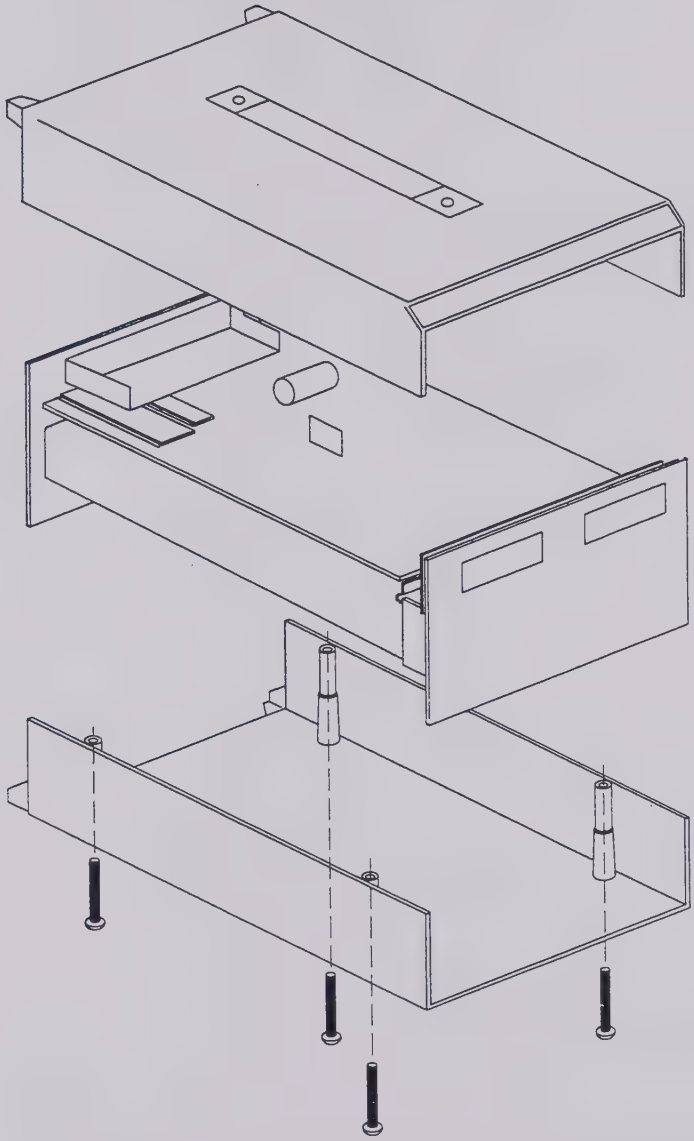


Figure 3-2. Model 3330 Exploded View

APPENDIX A
Model 3330 Specifications

A.1 MEASUREMENT PARAMETERS

Main Parameters (Display A) and Range

L: Inductance, 0.1nH to 19.999kH

C: Capacitance, 0.001pF to 199.99mF

R: Resistance, 0.1mΩ to 19.999MΩ

|Z|: Magnitude of impedance, 0.1mΩ to 19.999MΩ

AUTO: Automatically selects main parameters, sub-parameters, and equivalent circuit.

Sub-parameters (Display B) and Range

Q: Quality factor, 0.0001 to 19999

D: Dissipation factor, 0.0001 to 19999

ESR: Equivalent series resistance, 0.1mΩ to 19.999MΩ

G: Parallel conductance, 0.001μS to 199.99S

X: Series reactance, 0.1mΩ to 19.999MΩ

θ: Phase angle of impedance, –180.00° to +179.99°

V: Voltage monitor (RMS voltage across device) 0.0mV to 1.999Vrms

I: Current monitor (RMS current through device), 0.00μArms to 19.99mArms

Measurement resolution will vary depending on frequency, measurement range, and impedance phase angle.

Automatic Parameter Selection

Phase	Display A	Display B
+120° to +60°	L	Q
+30° to -30°	R	Q
-120° to -60°	C	D
others	|Z|	θ

Deviation Measurement

Δ: Deviation of main parameter (range of deviation is at least ±100% of the measurement range)

Δ%: % deviation display of main parameter (display range ±199.99%)

Note: Deviation and % deviation of sub-parameters cannot be displayed.

Execution Times

Measurement Time (IEEE-488)

FAST: 65msec (typ)

MED: 155msec (typ)

SLOW: 485msec (typ)

Note: 1kΩ impedance, 1kHz frequency and one shot trigger.

Autoranging Time: Approximately equal to measurement time

Stabilization Time After Range Change: 0.2 - 4.0s

Stabilization Time After Frequency Change: 0.15 - 4.0s

Bias Stabilization Time: (4 + 0.015C)s

where: C = capacitance of DUT (in μF)

Equivalent Circuits

AUTO: Automatic selection

SER: Series

PAR: Parallel

Automatic Equivalent Circuit Selection

Display A	Display B	Equivalent Circuit
L, C, R or |Z|	ESR or X	Series
L or C (|Z| ≤1kΩ)	Q, D, θ, V or I	Series
R (θ ≥ 0)	Q, D, θ, V or I	Series
|Z|	Q, D, θ, V or I	Series
L, C, R, or |Z|	G	Parallel
L or C (|Z| > 1kΩ)	Q, D, θ, V or I	Parallel
R (θ < 0)	Q, D, θ, V or I	Parallel

Displayed Resolution

4-1/2 digits (19999 max counts)

D, Q maximum resolution: 0.0001

θ resolution: 0.01°

V resolution: 0.1mV

I resolution: 1μA (when reference resistance is 100Ω)
0.1μA (when reference resistance is 1kΩ)
0.01μA (when reference resistance is 10kΩ or 50kΩ)

Note: Reference resistance is measurement range dependent.

Accuracy of V, I

Accuracy of V, I: ±(2% + |Z| accuracy)

Accuracy of |Z| and θ (1 year 18°-28°C)*

For 0.2Ω ≤ |Z| ≤ 20MΩ and 0.9-1.1V test level, see Table A-1.

For 0.2Ω ≤ |Z| ≤ 20MΩ and 50mV test level, see Table A-2.

For |Z| < 0.2Ω and 1V test level, see Table A-3.

For |Z| >20MΩ and 1V test level, see Table A-4.

*when properly zero corrected and using Model 3323A test fixture.

Specifications subject to change without notice.

Table A-1. Impedance Magnitude Accuracy (%) and Phase Accuracy (°)
Test Level= 0.9-1.1Vrms, Speed = Med or Slow

|Z| (Ω)	Frequency (Hz)								
	40 ~ 90	**100 ~ 130**	**160 ~ 900**	**1k**	**1.1k ~ 5.0k**	**5.1k ~ 10k**	**11k ~ 20k**	**21k ~ 50k**	**51k ~ 100k**
10M ≤ |Z| < 20M	4.5% 2.25°	3.0% 1.5°	2.0% 1.0°	1.0% 0.80°	2.0% 1.5°	3.5% 2.0°	4.0% 3.0°	14% 8.0°	20% 12°
5M ≤ |Z| < 10M	2.2% 1.3°	1.5% 0.90°	1.0% 0.60°	0.5% 0.40°	1.0% 0.60°	1.8% 1.1°	2.0% 1.3°	7.0% 4.0°	10% 6.0°
2M ≤ |Z| < 5M	1.10% 0.68°	0.75% 0.45°	0.5% 0.30°	0.3% 0.20°	0.5% 0.30°	0.9% 0.60°	1.0% 0.60°	3.5% 2.0°	5.0% 3.0°
1M ≤ |Z| < 2M	0.54% 0.33°	0.36% 0.22°	0.30% 0.15°	0.20% 0.10°	0.30% 0.15°	0.40% 0.20°	0.50% 0.30°	1.6% 1.0°	3.0% 2.0°
200k ≤ |Z| < 1M	0.37% 0.22°	0.25% 0.15°	0.20% 0.12°	0.15% 0.09°	0.20% 0.12°	0.27% 0.16°	0.35% 0.20°	1.0% 0.60°	2.0% 1.2°
20k ≤ |Z| < 200k	0.22% 0.15°	0.15% 0.10°	0.12% 0.06°	0.10% 0.04°	0.18% 0.08°	0.25% 0.15°	0.30% 0.20°	0.60% 0.40°	1.2% 0.8°
2k ≤ |Z| < 20k	0.21% 0.13°	0.14% 0.09°	0.12% 0.05°	0.10% 0.03°	0.12% 0.06°	0.15% 0.08°	0.20% 0.12°	0.40% 0.30°	0.80% 0.60°
10 ≤ |Z| < 2k	0.20% 0.12°	0.13% 0.08°	0.11% 0.05°	0.10% 0.03°	0.11% 0.08°	0.13% 0.10°	0.17% 0.15°	0.40% 0.25°	0.70% 0.50°
2 ≤ |Z| < 10	0.37% 0.22°	0.25% 0.15°	0.20% 0.10°	0.15% 0.07°	0.20% 0.12°	0.32% 0.20°	0.50% 0.30°	0.80% 0.40°	1.5% 0.80°
1 ≤ |Z| < 2	0.52% 0.33°	0.35% 0.22°	0.30% 0.20°	0.20% 0.12°	0.25% 0.15°	0.50% 0.30°	0.70% 0.40°	1.0% 0.60°	2.0% 1.2°
0.5 ≤ |Z| < 1	1.0% 0.68°	0.70% 0.45°	0.60% 0.40°	0.40% 0.25°	0.50% 0.30°	0.80% 0.50°	1.2% 0.70°	1.7% 1.0°	3.3% 2.0°
0.2 ≤ |Z| < 0.5	2.1% 1.3°	1.4% 0.90°	1.1% 0.70°	0.80% 0.50°	1.1% 0.70°	1.2% 0.80°	1.8% 1.1°	2.7% 1.6°	5.5% 3.0°

Notes:

1. For 5°C-18°C, or 28°C-40°C, multiply the |Z| accuracy by 1.4, and the phase accuracy by 1.8.
2. When measurement speed is FAST, multiply the accuracies by 2.0.
3. For test levels other than 0.9-1.1Vrms or 50mVrms see Accuracy Notes.

Table A-2. Impedance Magnitude Accuracy (%) and Phase Accuracy (°)
Level = 50mVrms, Speed = Med or Slow

|Z| (Ω)	Frequency (Hz)								
	40 ~ 90	100 ~ 130	160 ~ 900	1k	1.1k ~ 5.0k	5.1k ~ 10k	11k ~ 20k	21k ~ 50k	51k ~ 100k
10M ≤ |Z| < 20M	10.5% 6.0°	7.0% 4.0°	4.5% 2.5°	3.5% 2.0°	6.0% 3.5°	8.5% 5.0°	17% 10.0°	100% 60°	120% 70°
5M ≤ |Z| < 10M	5.25% 3.0°	3.5% 2.0°	2.2% 1.3°	1.7% 1.0°	2.7% 1.6°	3.5% 2.0°	7.0% 4.0°	50% 30°	60% 35°
2M ≤ |Z| < 5M	3.0% 1.8°	2.0% 1.2°	1.2% 0.80°	0.90% 0.60°	1.2% 0.8°	1.6% 1.0°	3.5% 2.0°	25% 15°	30% 18°
1M ≤ |Z| < 2M	1.5% 0.90°	1.0% 0.60°	0.60% 0.35°	0.40% 0.25°	0.60% 0.35°	0.80% 0.50°	1.6% 0.90°	12% 7.0°	14% 8.0°
200k ≤ |Z| < 1M	0.75% 0.45°	0.50% 0.30°	0.40% 0.25°	0.30% 0.18°	0.35% 0.20°	0.40% 0.25°	0.70% 0.40°	6.0% 3.6°	7.0% 4.0°
20k ≤ |Z| < 200k	0.45% 0.27°	0.30% 0.18°	0.20% 0.12°	0.16% 0.08°	0.24% 0.14°	0.32% 0.18°	0.40% 0.23°	1.8% 1.0°	3.0% 1.5°
2k ≤ |Z| < 20k	0.37% 0.23°	0.25% 0.15°	0.18% 0.09°	0.16% 0.06°	0.20% 0.12°	0.24% 0.14°	0.35% 0.20°	1.4% 0.80°	2.0% 1.2°
10 ≤ |Z| < 2k	0.30% 0.18°	0.20% 0.12°	0.18% 0.09°	0.15% 0.06°	0.20% 0.12°	0.23% 0.13°	0.32% 0.18°	1.2% 0.70°	1.6% 1.0°
2 ≤ |Z| < 10	0.75% 0.45°	0.50% 0.30°	0.35% 0.20°	0.25% 0.14°	0.35% 0.20°	0.50% 0.30°	0.70% 0.40°	3.4% 2.0°	4.0% 2.3°
1 ≤ |Z| < 2	1.5% 0.9°	1.0% 0.60°	0.60% 0.40°	0.50% 0.30°	0.60% 0.40°	0.80% 0.50°	1.1% 0.70°	6.0% 3.6°	8.0% 5.0°
0.5 ≤ |Z| < 1	2.7% 1.65°	1.8% 1.1°	1.2% 0.70°	1.0% 0.60°	1.2% 0.70°	1.5% 0.90°	1.8% 1.1°	10% 6.0°	14% 8.5°
0.2 ≤ |Z| < 0.5	5.55% 3.3°	3.7% 2.2°	2.6% 1.5°	2.0% 1.2°	2.6% 1.5°	2.9% 1.7°	3.4% 2.0°	21% 13°	28% 16°

Notes:

1. For 5°C-18°C, or 28°C-40°C, multiply the |Z| by 2.0, and the phase accuracy by 2.0.
2. When measurement speed is fast, multiply the accuracies by 2.0.
3. Accuracy is not guaranteed in the following ranges: |Z| > 20MΩ, |Z| < 0.2Ω.
4. For test levels other than 0.9-1.1Vrms or 50mVrms see Accuracy Notes.

Table A-3. Accuracy of |Z| and θ for |Z| <0.2Ω

|Z| (Ω)	LEVEL =1V rms, SPEED = MED or SLOW Frequency, (Hz)							
	100 120	200 500	1k	2k 5k	10k	20k	50k	100k
0≤|Z|<0.2	1.7% +0.2mΩ	1.5% +0.2mΩ	1.0% +0.2mΩ	1.3% +0.2mΩ	1.4% +0.3mΩ	2.0% +0.6mΩ	3.0% +1.5mΩ	6.0% +3mΩ

|Z| Accuracy: ±(% reading + R) shown.
θ Accuracy: (θ Accuracy for 0.2≤|Z|<0.5 in Table A-1) × (0.2Ω/|Z|)
When SPEED=FAST, multiply accuracy by 2.
For 5°-18°C or 28°-40°C, multiply accuracy by 2.

Table A-4. Accuracy of |Z| and θ for |Z|≥20MΩ

|Y| (S)	LEVEL =1V rms, SPEED = MED or SLOW Frequency, (Hz)							
	100 120	200 500	1k	2k 5k	10k	20k	50k	100k
0≤|Y|≤50nS	1.8nS	1.2nS	0.6nS	1.2nS	2.1nS	2.4nS	7.5nS	12nS

|Z| Accuracy: Specified by the ± deviation (S) of admittance |Y| shown.
θ Accuracy: (θ Accuracy for 10M≤|Z|<20M in Table A-1 × (|Z|/20MΩ).
When SPEED=FAST, multiply accuracy by 2.
For 5°-18°C or 28°-40°C, multiply accuracy by 2.

Accuracy Notes

1. When a measurement is made at line frequency or at twice line frequency, the measured value may deviate beyond the accuracy range due to interaction with line frequency. In this case, use 50Hz or 100Hz for a 60Hz line and 60Hz or 120Hz for a 50Hz line.
2. Tables A-1 through A-4 show the worst case value in each impedance range. A more precise value for accuracy may be obtained by interpolation.
3. In order to determine the impedance magnitude accuracy (A_Z) and impedance phase accuracy (A_θ) at measurement signal levels (LV) other than 50mV or 0.9V - 1.1V, use one of the following equations:

Measurement Signal Level (LV) From To	Measured Impedance Magnitude |Z|	Impedance Magnitude Accuracy [%] (A_Z)	Impedance Phase Accuracy [°] (A_θ)
10mV 49mV	<20MΩ and ≥0.2Ω	$A_{Z2}\left(\frac{50mV}{LV}\right)$	$A_{\theta2}\left(\frac{50mV}{LV}\right)$
51mV 899mV	≥20MΩ	$A_{Z4}\left(\frac{1V}{LV}\right)$	$A_{\theta4}\left(\frac{1V}{LV}\right)$
51mV 899mV	<20MΩ and ≥0.2Ω	$A_{Z1}+\left[(A_{Z2}-A_{Z1})\left(\frac{50mV}{LV}\right)\right]$	$A_{\theta1}+\left[(A_{\theta2}-A_{\theta1})\left(\frac{50mV}{LV}\right)\right]$
51mV 899mV	<0.2Ω	$A_{Z3}\left[1+\left(\frac{100mV}{LV}\right)\right]\left(\frac{0.2\Omega}{\lvert Z\rvert}\right)[\%]+B_{Z3}\,[m\Omega]$	$A_{Z5}\,[\%]\times 0.6°$

where:

LV = Test level voltage

A_{Z1} = Impedance Magnitude Accuracy (%) from Table A-1

$A_{\theta1}$ = Impedance Phase Accuracy (°) from Table A-1

A_{Z2} = Impedance Magnitude Accuracy (%) from Table A-2

$A_{\theta2}$ = Impedance Phase Accuracy (°) from Table A-2

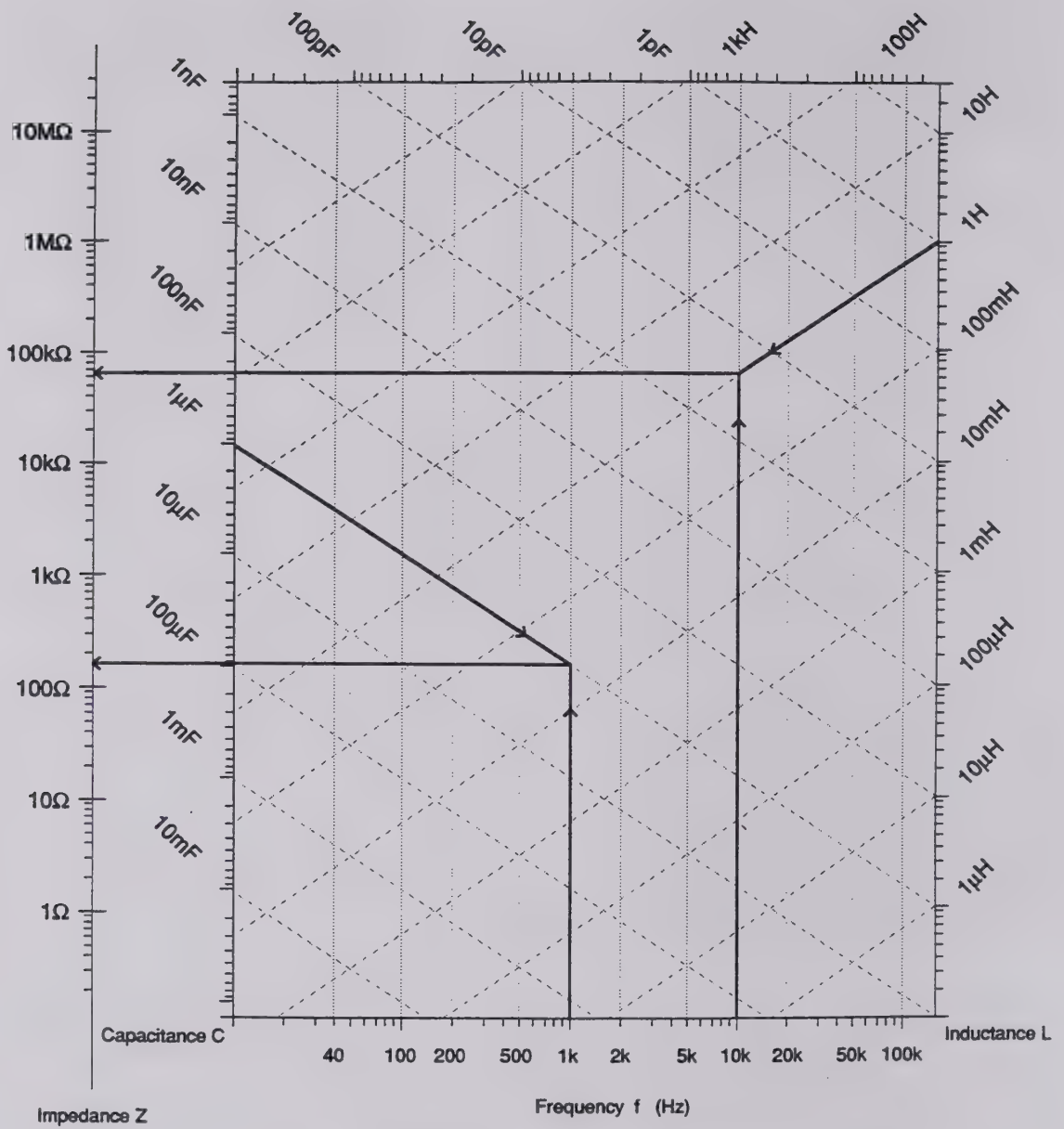
A_{Z3} = Impedance Magnitude Accuracy (%) from Table A-3

B_{Z3} = Impedance Magnitude offset (mΩ) from Table A-3

A_{Z4} = Impedance Magnitude Accuracy (%) from Table A-4

$A_{\theta4}$ = Impedance Phase Accuracy (°) from Table A-4

A_{Z5} = Impedance Magnitude Accuracy for 51mV ≤ LV ≤ 899mV and $|Z| < 0.2\Omega$



Notes: Use this chart to determine the impedance magnitude of an inductor or capacitor at a particular frequency. For example, a 1H inductor at 10kHz and a 1µF capacitor at 1kHz are shown on the diagram.

1H @ 10kHz = 63kΩ
1µF @ 1kHz = 160Ω

Figure A-1. Conversion Diagram

Examples of Determining Accuracy

Example 1: Component = 33kΩ resistor
Test Frequency = 10kHz
Test Level = 1V rms
Temperature = 18°-28°C
Speed = Med or Slow

1. Find the accuracy values corresponding to 33kΩ and 10kHz on Table A-1. Record the impedance magnitude accuracy (0.25%) and impedance phase accuracy (0.15°).
2. If the ambient temperature is 5°C - 18°C or 28°C - 40°C, multiply the impedance magnitude accuracy by 1.4 and the impedance phase accuracy by 1.8.
3. If measurement speed is set to FAST, multiply the impedance magnitude accuracy by 2.0 and the impedance phase accuracy by 2.0.
4. Resistance accuracy is approximately equal to the impedance magnitude accuracy if $Q \leq 0.1$.
5. If $Q > 0.1$, see example 4.

Example 2: Component = 10µF capacitor
Test Frequency = 1kHz
Test Level = 50mV
Temperature = 18°-28°C
Speed = Med or Slow

1. Determine the impedance of the 10µF capacitor at 1kHz by referring to Figure A-1 or by solving the following equation:

$$|Z| = \frac{1}{2\pi fC} = \frac{1}{2\pi \times 1\text{kHz} \times 10\mu\text{F}} = 16\Omega$$

2. Find the accuracy values corresponding to 16Ω at 1kHz on Table A-2. Record the impedance magnitude accuracy (0.15%) and impedance phase accuracy (0.06°).
3. If the ambient temperature is 5°C - 18°C or 28°C - 40°C, multiply the impedance magnitude accuracy by 1.4 and the impedance phase accuracy by 1.8.
4. If measurement speed is set to FAST, multiply the impedance magnitude accuracy by 2.0 and the impedance phase accuracy by 2.0.
5. If $D \leq 0.1$, the accuracy of the capacitance measurement accuracy (C_{acc}) is related to the impedance magnitude accuracy (Z_{acc}) by the following equation:

$$C_{acc} = \frac{Z_{acc}}{1 - Z_{acc}}$$

In this example $Z_{acc} = 0.1\%$ and $C_{acc} = 0.1001\%$.

6. If $D > 0.1$, see example 4.

Example 3: Component = 680µH
Test Frequency = 100kHz
Test Level = 1V rms
Temperature = 18°-28°C
Speed = Med or Slow

1. Determine the impedance magnitude accuracy of the 680µH inductor at 100kHz by referring to Figure A-1 or by solving the following equation:

$$|Z| = 2\pi fL = 2\pi \times 100\text{kHz} \times 680\mu\text{H} = 427\Omega$$

2. Find the accuracy values corresponding to 427Ω at 100kHz on Table A-1. Record the impedance magnitude accuracy (0.7%) and impedance phase accuracy (0.5°).
3. If the ambient temperature is 5°C - 18°C or 28°C - 40°C, multiply the impedance magnitude accuracy by 1.4 and the impedance phase accuracy by 1.8.
4. If measurement speed is set to FAST, multiply the impedance magnitude accuracy by 2.0 and the impedance phase accuracy by 2.0.
5. If $Q > 10$ the inductance measurement accuracy is approximately equal to the impedance magnitude accuracy.
6. If $Q < 10$, see example 4.

Example 4: Determine precision of parameters other than $|Z|$ and θ at any frequency.

1. First, measure $|Z|$ and θ. Or, calculate them from other measured parameters by applying the following equations:

θ_{meas}	$= \arctan Q$	$Q = 1/D$
$\|Z\|_{meas}$	$= 2\pi fL_S/\sin\theta$	$= 2\pi fL_S/ESR$
	$= 1/(2\pi fC_S \sin\theta)$	$= 1/(2\pi fC_S\, ESR)$
	$= 2\pi fL_P \sin\theta$	$= (2\pi fC_P)/G$
	$= \sin\theta/(2\pi fC_P)$	$= 1/(2\pi fL_P\, G)$

where:

f = frequency (Hz).

C_S, L_S = series equivalent circuit variables.

C_P, L_P = parallel equivalent circuit variables.

2. Determine the impedance magnitude accuracy (A_Z) and impedance phase accuracy (A_θ) of $|Z_{meas}|$ and θ_{meas} by referring to the appropriate table (Table A-1, A-2, A-3 or A-4).
3. Determine the maximum and minimum value by using the following equations:

$Z_{max} = |Z|_{meas} \times (1 + A_Z)$
$Z_{min} = |Z|_{meas} \times (1 - A_Z)$
$\theta_{max} = \theta_{meas} + A_\theta$
$\theta_{min} = \theta_{meas} - A_\theta$

4. Determine the maximum and minimum value of the parameter of interest by substituting the values found in step 3 into one of the following equations. There will be four combinations:

R_S	$= \|Z\| \cos\theta$	R_P	$= \|Z\|/\cos\theta$
ESR	$= \|Z\| \cos\theta$	G	$= \cos\theta/\|Z\|$
X	$= \|Z\| \sin\theta$	B	$= \sin\theta/\|Z\|$
L_S	$= X/2\pi f$	L_P	$= -1/2\pi fB$
C_S	$= -1/2\pi fX$	C_P	$= B/2\pi f$
Q	$= \|\tan\theta\|$	D	$= 1/\|\tan\theta\|$

5. Accuracy is found by determining the largest deviation from the measured values.

A.2 MEASUREMENT SIGNAL

Frequency

Range:
40Hz-130Hz: 10Hz steps
160, 200, 250Hz
300Hz-9.9kHz: 100Hz steps
10kHz-100kHz: 1kHz steps
Accuracy: ±0.005%

Output Impedance: 100Ω (typ)

Signal Level (voltage when drive terminal HCUR is open)
Range: 10mVrms-1.100Vrms: 1mV steps
Accuracy:
±(3% + 1mV) for 1kHz
±(4% + 1mV) for 40Hz-20kHz
±(5% + 1mV) for 21kHz-100kHz)

Bias Voltage

Internal: 0 or +2VDC (±5%)
External: 0 to ±35VDC

A.3 COMPARATOR/BINNING FUNCTIONS

Number of bins: 20.
The comparator function can sort on the main parameters (R, L, C, or Z) into bins 1-19. Also, the comparator function can sort on the sub-parameter into bin 0 (Q, D, ESR, G or X).

A.4 FRONT PANEL SET-UP MEMORY

Number of front panel set-ups: 10.
Front panel set-up contents: All front panel parameters except bias control.
Battery life: At least 3 years if storage temperture is less than 40°C.

A.5 HANDLER INTERFACE

Connector: 36-pin Centronics type (Cinch 57-30360)
Output signals:
BIN 0-11: Bin judgment signals
A_NG: Main parameter failure
B_NG: Sub-parameter failure
STROBE: Judgment completion pulse (pulse width ≥1.5ms)
BUSY: Measurement in progress flag

Output characteristics:
Type: TTL negative logic
Maximum TTL load: 10 standard TTL
Maximum output current: 48mA (sink, output voltage ≤1V)
Input signals:
TRIG: Measurement start trigger (pulse width ≥100μs)
LOCK: Panel operation prohibited
Input characteristics:
Low level input voltage: -1.5 to +0.8V
High level input voltage: +2.4V to 30V (TRIG), +3.5V to 30V (LOCK)
Low level input current (Approximation)
TRIG: -0.33mA
LOCK: -3mA
Handler Interface Ground: isolated from chassis ground. Max voltage from chassis ±42VDC.
Beeper (two functions, dip switch selectable):
Beeper on/off: Enables beeper function.
Beeper Mode:
1. Beep only for NO GO
2. 4KHz beep for GO and 2kHz beep for NO GO.

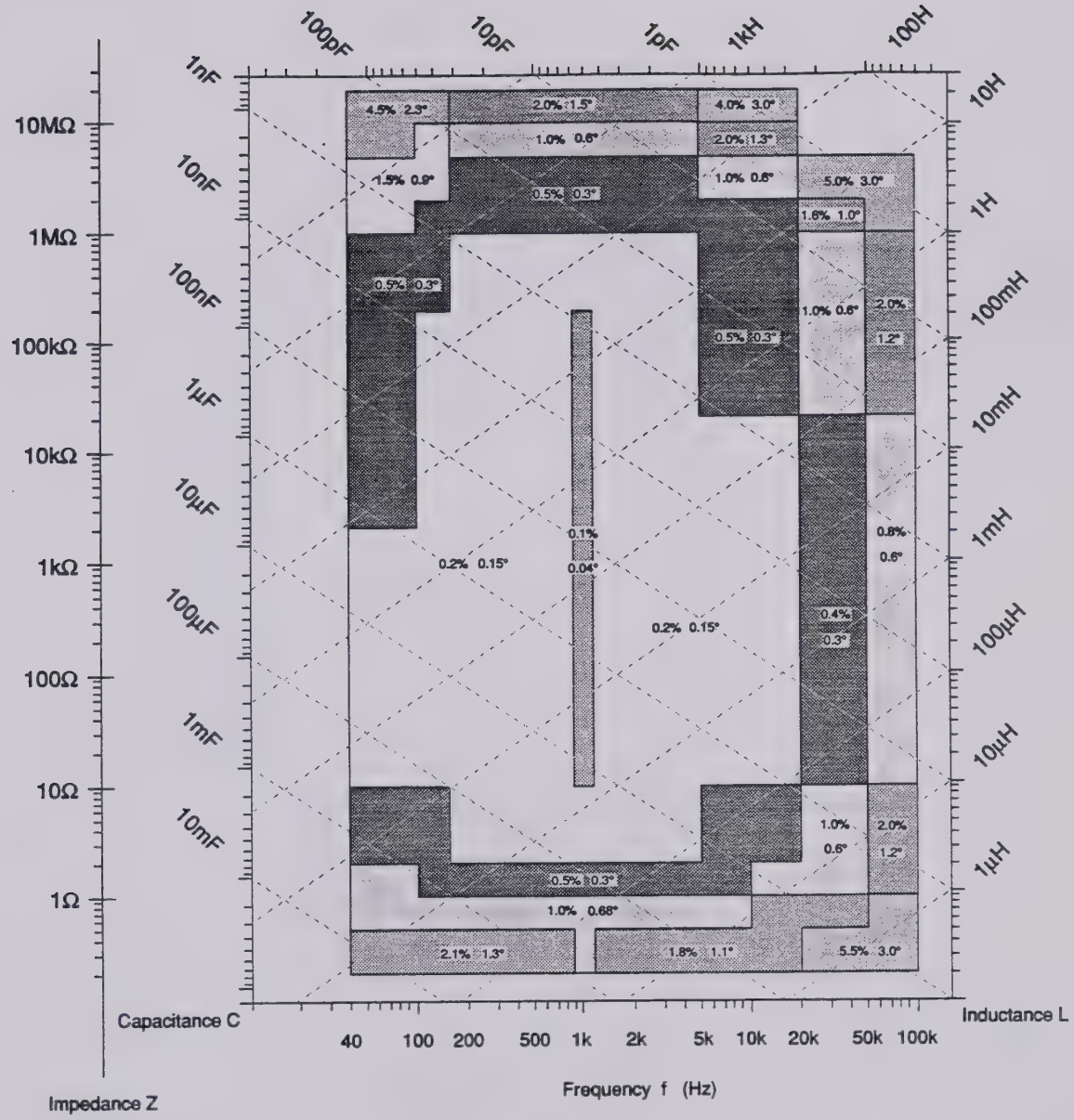
Note: GO refers to comparator bins 1-19, and NO GO refers to comparator bin 0.

A.6 IEEE-488 BUS IMPLEMENTATION

Multiline Commands: DCL, SDC, GET, GTL, UNT, UNL, SPE, SPD
Uniline Commands: IFC, REN, EOI, SRQ, ATN
Interface Functions: SH1, AH1, T5, L4, SR1, RL2, PP0, DC1, DT1, C0.

A.7 GENERAL

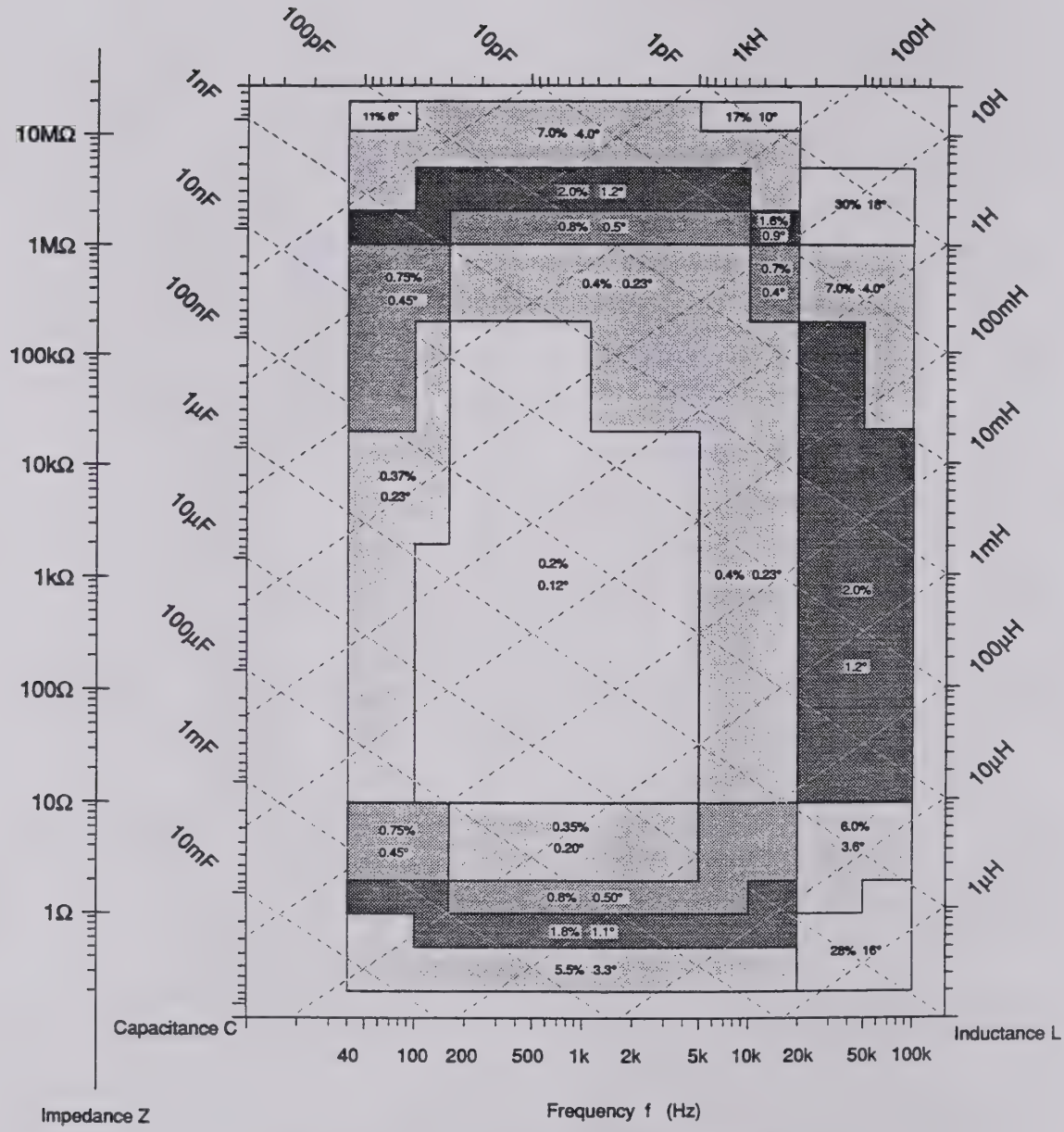
Line Voltage: 100, 120, 220 or 240 ±10% VAC (external switch selectable)
Environment: Operating: 0°~40°C, 10~90% RH (non-condensing)
Storage: -10°~50°C, 10~80% RH (non-condensing)
Dimensions, Weight: 132.5mm high × 216mm wide × 350mm deep (5 ¼ in. × 8 ½ in. × 13 ¾ in.) Net weigth 3.7kg (8.1 lbs.) (instrument only, excluding accessories).
Warm-up: 30 minutes.
Front Panel Connectors: 4 BNC connectors and a five way binding post.
Rear Panel Connectors:
Handler Interface
External Bias: BNC
IEEE Connector: Floating
Display: Two 4 ½ digit displays for main and sub-parameters.
Trigger Mode: Automatic (continuous) and manual.
Trigger Delay Time: 0-199.99s
Calibration Cycle: 1 year



Note : 1. For 5°C-18°C, or 28°C-40°C, multiply the |Z| accuracy by 1.4, and the phase accuracy by 1.8.
2. When measurement speed is FAST, double the accuracy.

Level = 0.9V-1.1V rms Speed = Medium or Slow

Figure A-2. Accuracy Diagram



Note : 1. For 5°C-18°C, or 28°C-40°C, multiply the |Z| accuracy by 2.0, and the phase accuracy by 2.0.
2. When measurement speed is FAST, double the accuracy.
3. Accuracy is not guaranteed in the following ranges : |Z|>20MΩ, |Z|<.2Ω.

Level = 50mV rms Speed = Medium or Slow

Figure A-3. Accuracy Diagram

Index

A

Analyzer, 2-5

B

Battery Replacement, 3-2
Block Diagram, 2-1

C

Calibration, 3-1
Capacitance Reading Checks, 1-11
Cover Removal, 3-2
Current and Voltage Detection, 2-1
Current-to-Voltage Converter, 2-5

E

Environmental Conditions, 1-2, 1-7
External Bias Fuse, 3-1
External DC Bias Voltage Range, 1-6

F

Factory Service, 3-2
Fan Filter Cleaning, 3-2
Frequency Accuracy, 1-3
Fuse Replacement, 3-1

I

Impedance Calculation, 2-1
Inductance Reading Checks, 1-11
Initial Conditions, 1-1
Internal Bias Voltage Accuracy, 1-6

L

Line Fuse, 3-1
Line Power, 1-1

M

Measurement Accuracy Tests, 1-7
Measurement Signal Destination, 1-4
Measurement Signal Level Accuracy, 1-3
Measurement Signal Tests, 1-2

O

Operation Check Procedure, 3-4
Ordering Parts, 3-5
Oscillator, 2-4
Output Impedance Accuracy, 1-4

P

Parts List, 3-5
Performance Verification, 1-1
Principles of Operation, 2-1

R

Recommended Equipment, 1-7
Recommended Test Equipment, 1-2
Repair, 3-2
Repair Summary, 3-4
Resistance Standards Accuracy, 1-7

S

Service Information, 3-1

V

Verification Limits, 1-1

KEITHLEY

SERVICE FORM

Model No. _____ **Serial No.** _____ **Date** _____

Name and Telephone No. _____

Company _____

List all control settings, describe problem and check boxes that apply to problem. _____

_____

_____

☐Intermittent ☐Analog output follows display ☐Particular range or function bad; specify _____
☐IEEE failure ☐Obvious problem on power-up ☐Batteries and fuses are OK
☐Front panel operational ☐All ranges or functions are bad ☐Checked all cables

Display or output (circle one)

☐Drifts ☐Unable to zero
☐Unstable ☐Will not read applied input
☐Overload

☐Calibration only ☐Certificate of Calibration required
☐Data required

(attach any additional sheets as necessary.)

Show a block diagram of your measurement system including all instruments connected (whether power is turned on or not). Also, describe signal source.

Where is the measurement being performed? (factory, controlled laboratory, out-of-doors, etc.)

_____

_____

What power line voltage is used? _____ Ambient Temperature? _____ °F

Relative humidity? _____ Other? _____

Any additional information. (If special modifications have been made by the user, please describe.) _____

_____

Be sure to include your name and phone number on this service form.

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